HUMANE TRAP OPTIMIZATION

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by

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SCOPE AND CONTENTS:

Optimization criteria for trap design were established and a qualitative optimization program on the design of two of the most promising series of traps was carried out.

An evaluation of several existing traps was carried out using Johnston's technique. Two traps were calibrated and an impact testing device was designed and built for future research work to be conducted at Guelph University.

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PART I

EVALUATION

CHAPTER I - TRAPS AND CHARACTERISTICS

A. Introduction

The first phase of the Humane Trap Development project was carried out by N. Johnston, Department of Mechanical Engineering, McMaster University, Hamilton, 1970. The work is well documented in his thesis "HUMANE TRAP EVALUATION". (1)*

The first part of the present project is a continuation of Johnston's work. In his work Johnston developed a technique for testing and evaluating traps as well as a set of standardized scales to which traps can be compared. These scales are called "MODIFIED CONIBEAR SCALES" since the traps of the Conibear-series were used as standards in evaluating all other traps. The energy values of both the trap under evaluation and the appropriate Conibear values are shown in all data sheets.

The established "Johnston-Beke technique" was adapted to the first part of the author's project in order to evaluate a number of traps which were developed either as a totally new design or as an extensive modification over a previous model after the completion of Johnston's project. This work on additional traps helped to provide more comprehensive evaluation of the humane qualities of existing traps and gave the author a chance to better appreciate the many

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* Numbers in brackets designate REFERENCES

factors and features which needed to be taken into consideration in the optimization process.

The first part of the project was concluded with the calibration of two traps to be used for future research and field work at Guelph University. Also, for the same purpose a test device which develops impact-energies in the range of approximately 25 in-lb to 600 in-lb was designed and built. (See APPENDIX C)

B. Traps Considered for Evaluation

After the completion of N. Johnston's work, several new traps as well as modified ones were developed.

The traps evaluated in this project which can be considered to be modifications of previously existing models are:

(i) The New Instant Killer
(ii) The New Compensator
(iii) The Small Mohawk
(iv) The Large Mohawk
(v) The New Conibear 330-model

The following can be considered to be new in design:

(i) The Canada Trap
(ii) The New Jacob Trap
(iii) The New Conibear 110-model
(iv) The New Conibear 220-model

A modification of a previously existing model refers to a mechanism which has undergone only minor changes such as a stronger spring, reduction or increase in overall geometry of the mechanism, use of different material for frame, etc. In such cases, the basic shape and the manner of functioning (positioning, triggering) of a particular trap remained. A new design of a trap, however, refers to a mechanism that has undergone major changes as far as the shape of the frame or the type of spring or trigger is concerned.

C. Trap Characteristics for Evaluation

The results of the evaluation of all the modified traps listed in the previous section will only show their primary characteristics as defined by N. Johnston. (2)

Primary characteristics include:

- energy at different jaw openings (above and below water)
- closing time
- clamping force
- prying force
- spring modulus
- moment of inertia
- weight

The secondary characteristics are not affected to the extent which would necessitate a complete description of these, as they are well documented in Johnston's thesis and would be only repetitive here. However, should a secondary characteristic of a particular trap be greatly affected it will be mentioned.

The results of the evaluation of all traps categorized as new designs will show primary characteristics as well as a qualitative analysis of the traps features. The qualitative analysis of both the New Jacob Trap and the New Conibear Series, however, will be included in PART II, which deals with the optimization of both types of traps. It should be noted that the evaluation of the Jacob Traps took place after the optimization of their design had been completed. However, for easy comparison of primary characteristics the results of all traps under consideration have been compiled together. The traps of the Conibear Series were tested and evaluated as they were received.

The test results from the evaluation program have been issued in a separate report to the Humane Trap Development Committee.

CHAPTER II -- EVALUATION

A. New Instant Killer

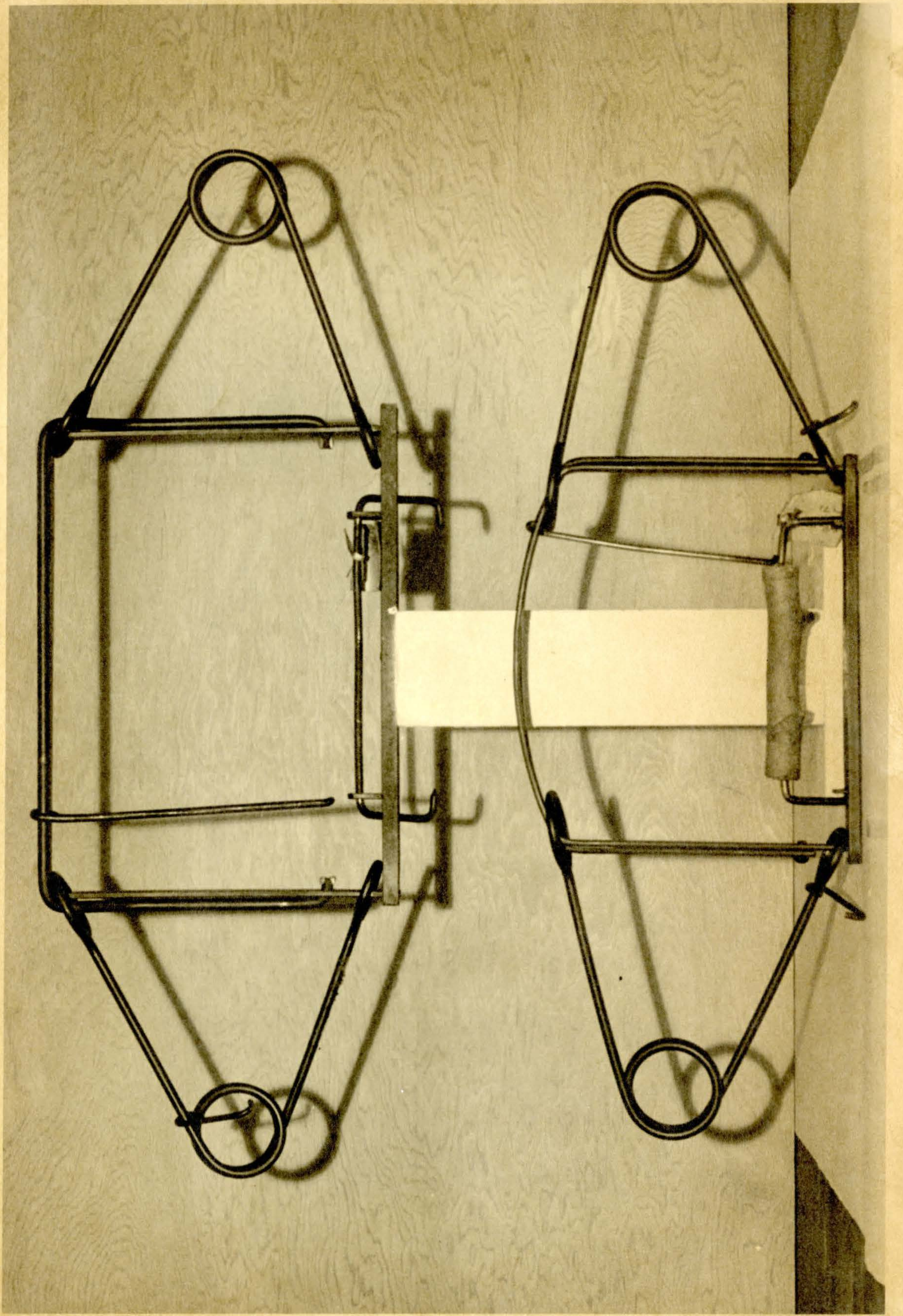
The New Instant Killer is a modified version of the Northern Killer which was tested and evaluated by N. Johnston. Qualitatively both mechanisms are very similar as far as the basic shape of the frame, the approximate 90 degree rotation of the jaw and the trigger mechanism is concerned. (See Fig. 1) The upper trap in Fig. 1 is the Northern Killer, while the lower trap is the New Instant Killer. The material used for the rotating jaw changed from 0.370 inches diameter round steel to a .750 inch x .175 inch flat steel. Also, the open space inside the trap was reduced from 14.2 inches x 10.25 inches = 145.53 inches^2 to 11.2 inches x 8.5 inches = 95.2 inches^2.

The springs which power the traps are identical in both models.

Clamping and prying force is measured perpendicular to the jaws.

The results of the New Instant Killer vary from the results of the Northern Killer obtained by N. Johnston. The energy values of the New Instant Killer, especially above water, decreased and the clamping force increased. This variation is due mainly to the modified configuration of the trap. The spring travel decreased by approximately

Fig. 1



2.0 inches which results in a decreased spring extension. (Compare spring travel of both traps in Fig. 1). This of course means that a substantial amount of potential energy stored in the spring is not being converted into kinetic energy. The static force in the spring on the other hand increases with increased tensioning of the spring. For this reason the clamping force in the trap increased.

TRAP SPECIFICATION AND DATA SHEET

TRAP NAME	New Instant Killer
TRAP MODEL	- - -
TRAP TYPE	Production
SPRING MODULUS	12.953 in-lb/deg.
MOMENT OF INERTIA	38.007 lb-in^2
WEIGHT OF TRAP	4.9 lb.
EQUIVALENT CONIBEAR MODEL NO.	330
APPROXIMATE HEIGHT (in.)	9.0 in.

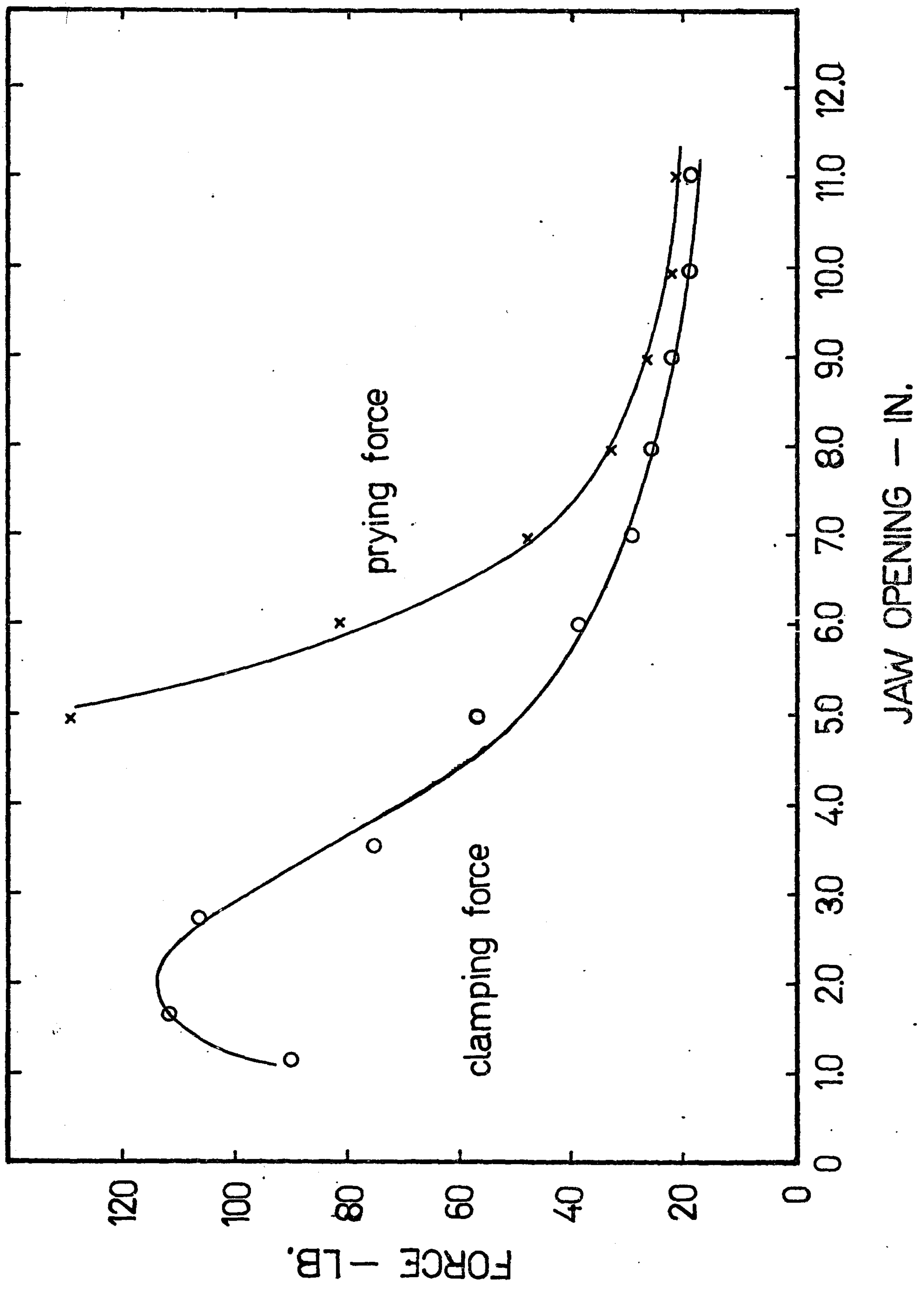
ENERGY (in.-lb.) ABOVE WATER

	New Instant Killer	Conibear No. 330
MAX.	218.16	351
6"	122.71	304
4"	127.71	351
2"	127.71	277
CLOSING TIME (milliseconds) (to 2")	45.1	40.5

ENERGY (in.-lb.) BELOW WATER

	New Instant Killer	Conibear No. 330
MAX.	125.82	176
6"	87.37	176
4"	125.82	138
2"	125.82	63
CLOSING TIME (milliseconds) (to 2")	47.6	50.6

THE NEW INSTANT KILLER



B. New Compensator

The New Compensator is a modified version of the Dahlgren Compensator which was tested and evaluated by N. Johnston. Both models are identical as far as the frame, the horizontal crossbar and the trigger is concerned. (See Fig. 2) The upper trap shown is the Dahlgren Compensator while the lower trap is the New Compensator.

The spring has undergone the following changes:

	Dahlgren Compensator	New Compensator
diameter of spring wire	0.250 in.	0.312 in.
mean diameter of coil	2.680 in.	2.750 in.
moment arm of spring	approx. 8.5 in.	approx. 10.5 in.

Clamping and prying force is measured perpendicular to the jaws.

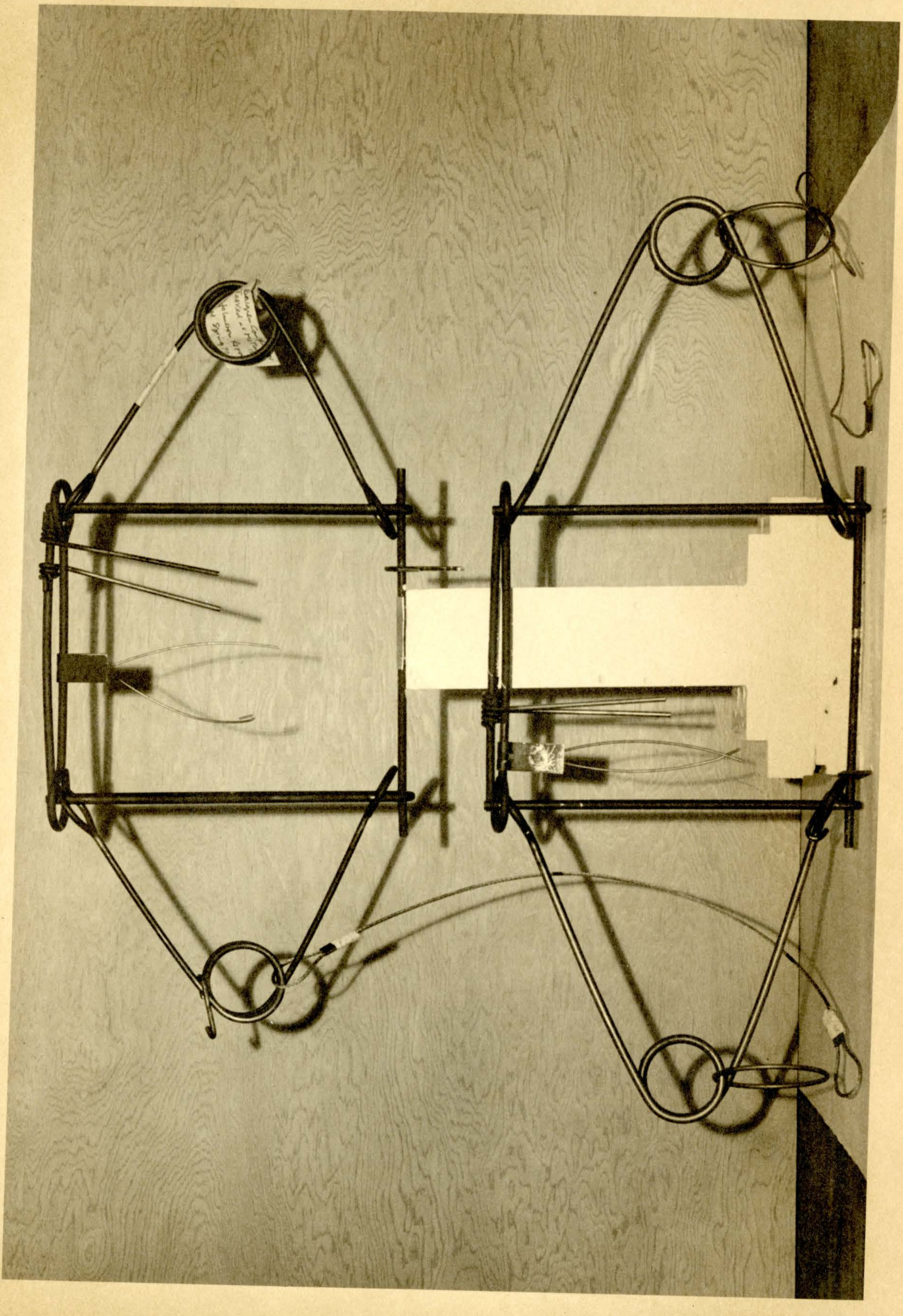
The results of the New Compensator vary from the results of the Dahlgren Compensator obtained by N. Johnston. The energy values of the New Compensator, are below those which were expected from a stronger spring. The performance below water suggests a more detailed investigation of the entire under water problem, which is outlined under <u>Recommendations For Further Work</u> at the end of PART II. The clamping force has essentially remained at the values of the Dahlgren Compensator. For the present the low performance of the trap above water is to be attributed to the alteration of the spring. The wire diameter of the helical coil of the spring has been increased, however, at the same time the moment arms of the spring have been increased by approximately 2.0 inches. (Compare springs of both traps in Fig. 2).

This results in a decreased angular deflection and preloading of the modified helical coil and decreased potential energy being converted into kinetic energy, which would not be the case if the spring could move through a larger angular deflection. Due to the increase in moment arm, the static force (clamping and prying force) did not improve.

Fig. 2

Dahlgren Compensator

New Compensator



TRAP SPECIFICATION AND DATA SHEET

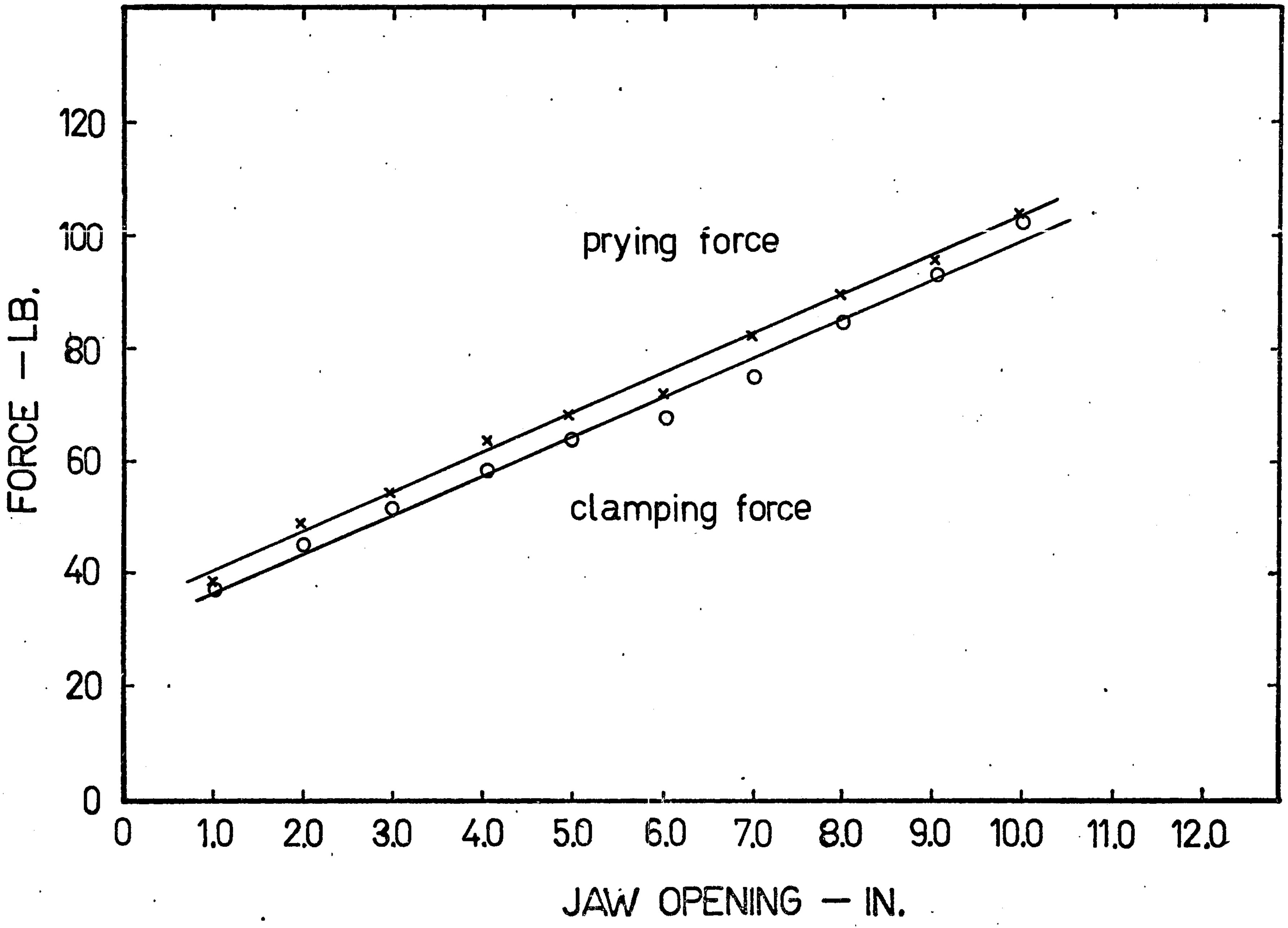
TRAP NAME.	New Compensator
TRAP MODEL	- - -
TRAP TYPE.	Production
SPRING MODULUS	12.25 in-lb/deg.
MOMENT OF INERTIA.	0.393 lb.
WEIGHT OF TRAP	4.8 lb.
EQUIVALENT CONIBEAR MODEL NO.	330
APPROXIMATE HEIGHT (in.)	12.0 in.

ENERGY (in.-lb.) ABOVE WATER

	New Compensator	Conibear No. 330
MAX.	166.89	351
6"	166.89	304
4"	115.89	351
2"	166.89	277
CLOSING TIME (milliseconds). . . (to 2")	22.1	40.5

ENERGY (in.-lb.) BELOW WATER

	New Compensator	Conibear No. 330
MAX.	52.6	176
6"	52.6	176
4"	13.1	138
2"	29.5	63
CLOSING TIME (milliseconds). . . (to 2")	32.7	50.6



THE NEW COMPENSATOR

C. Small Mohawk

The Small Mohawk which was included in the present project is the same trap as the one previously evaluated by Johnston. The primary reason for including this trap in the present evaluation was to obtain a calibrated mechanism whose spring tension could be adjusted to develop various energy ranges throughout the motion of the trap. It is expected that this trap will be used in the research program at Guelph University.

A modification had been carried out on the trap which made it possible to alter the preload of the springs. By depressing and subsequently turning the adjustment bar a desired preload of the spring could be obtained.

The Small Mohawk has ten different settings which can be determined from a dial located behind the adjustment bar. The dial carries numbers from one to six through one complete cycle. The ten settings are 1.1 - 1.6, 2.1 - 2.4. The first number in each combination defines the cycle, the second number the intermediate station within a cycle. A set of energy tables has been compiled for each individual spring setting showing energies at various jaw openings. After the alteration of the preload mechanism had been carried out it became apparent that the spring supplied with the Small Mohawk could not be adjusted to more than three settings without overstressing and subsequent yielding of the spring material. A calibrated trap with only two or three energy ranges would not be sufficiently versatile, and for this reason a new spring was designed and manufactured which now allowed the ten different settings described before.

The results of the evaluation listed on the following page refer to the full-power setting of the trap with the spring adjustment at station 2.4.

Clamping and prying force are measured perpendicular to the jaws.

The experimentally obtained incremented values for energy and closing time of all ten spring settings have been compiled and submitted under the separate report.

for

picture of Small Mohawk

see N. Johnston's Thesis

"HUMANE TRAP EVALUATION"

TRAP SPECIFICATION AND DATA SHEET

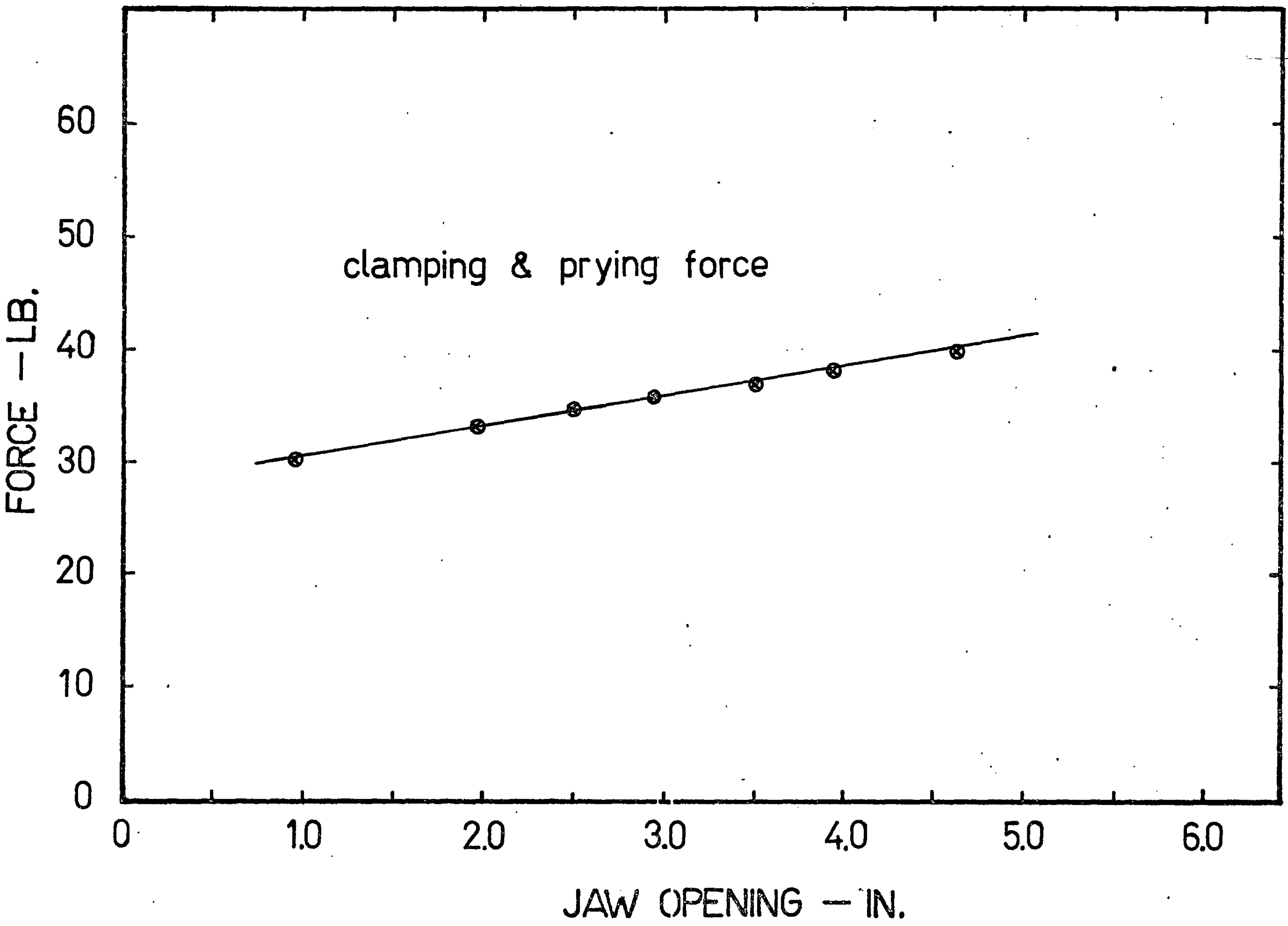
TRAP NAME	Mohawk
TRAP MODEL	Small
TRAP TYPE	Prototype
SPRING MODULUS	0.0806 in-lb/deg.
MOMENT OF INERTIA	1.462 in^2-lb
WEIGHT OF TRAP	2.0 lb.
EQUIVALENT CONIBEAR MODEL NO	110
APPROXIMATE HEIGHT (in.)	6.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Mohawk	Conibear No. 120
MAX.	216.04	31.49
6"	- -	- -
4"	89.28	20.60
2"	176.85	31.49
CLOSING TIME (milliseconds). (to 2")	10.8	17.7

ENERGY (in.-lb.) BELOW WATER

	Mohawk	Conibear No. 120
MAX.	59.66	17.04
6"	- -	- -
4"	54.36	9.2
2"	54.36	13.06
CLOSING TIME (milliseconds). (to 2")	15.1	19.8



SMALL MOHAWK

D. Large Mohawk

The Large Mohawk had been calibrated by Johnston in a similar fashion to the Small Mohawk which was previously described. The purpose of including the Large Mohawk in the present evaluation was to check the calibration and energy values obtained from a new set of springs so that the research work conducted at Guelph would not be delayed should one of the springs fail in testing.

A further reason to include the Large Mohawk was to test the loss of energy under water, which was not previously carried out for this trap.

The results of the evaluation listed on the following page refer to the full-power setting of the trap with the spring adjustment at station 2.4.

Clamping and prying force are measured perpendicular to the jaws.

The experimentally obtained incremented values for energy and closing time of all twelve spring settings have been compiled and submitted under the separate report.

picture of Large Mohawk

not available

TRAP SPECIFICATION AND DATA SHEET

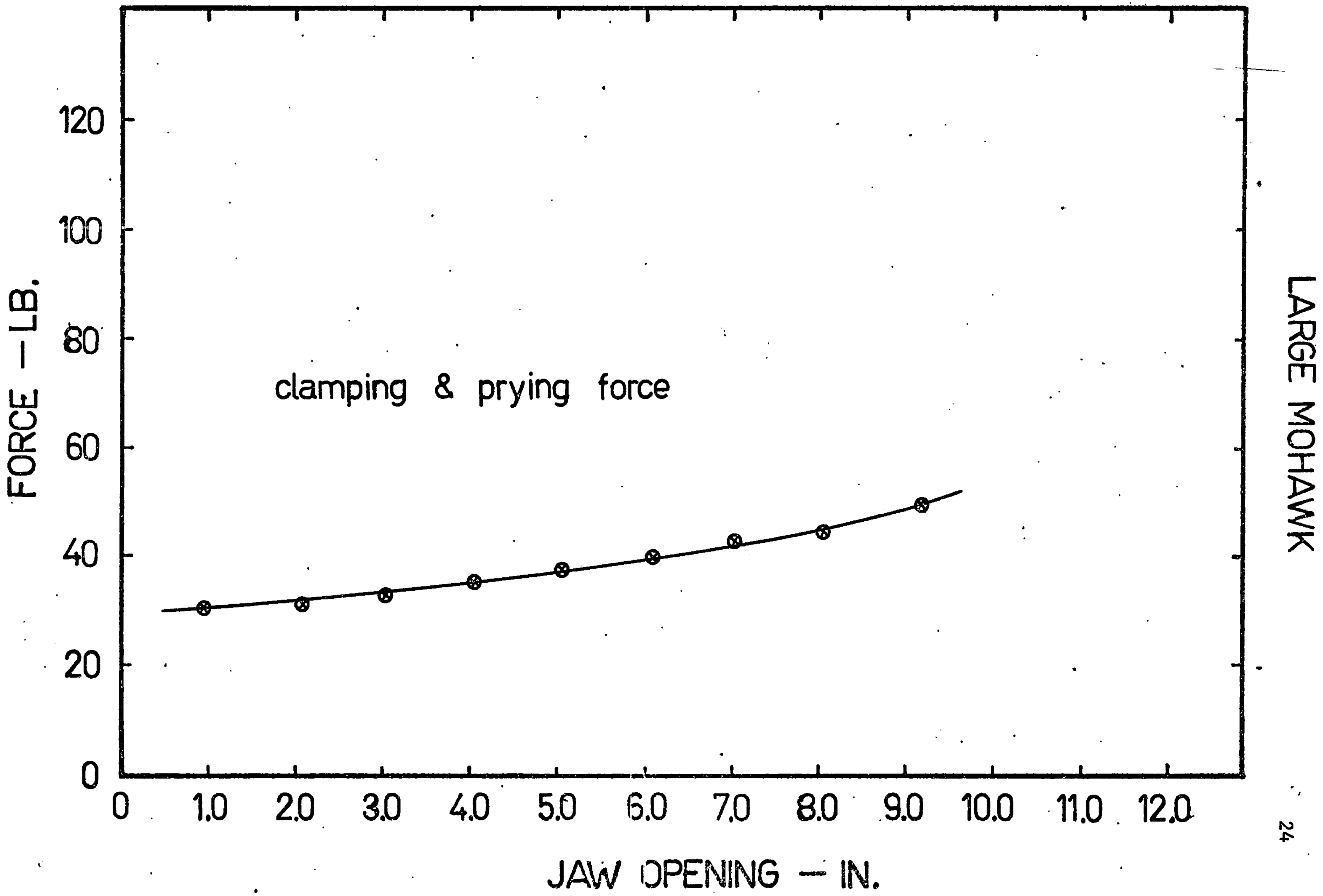
TRAP NAME.	Mohawk
TRAP MODEL	Large
TRAP TYPE.	Production
SPRING MODULUS	0.19156 in-lb/deg.
MOMENT OF INERTIA.	16.6743 in^2-lb
WEIGHT OF TRAP	4.875 lb.
EQUIVALENT CONIBEAR MODEL NO.	330
APPROXIMATE HEIGHT (in.)	11.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Large Mohawk	Conibear No. 330
MAX.	504.24	351
6"	314.28	304
4"	357.58	351
2"	504.24	277
CLOSING TIME (milliseconds). . . (to 2")	31.5	40.5

ENERGY (in.-lb.) BELOW WATER

	Large Mohawk	Conibear No. 330
MAX.	68.89	176
6"	68.89	176
4"	68.89	138
2"	68.89	63
CLOSING TIME (milliseconds). . . (to 2")	54.1	50.6


FORCE —LB.
120
100
80
60
40
20
0
clamping & prying force
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
JAW OPENING — IN.
LARGE MOHAWK

E. Canada Trap

The Canada Trap is considered to be a new design amongst those already included in the Humane Trap Development Program. (See Fig. 3)

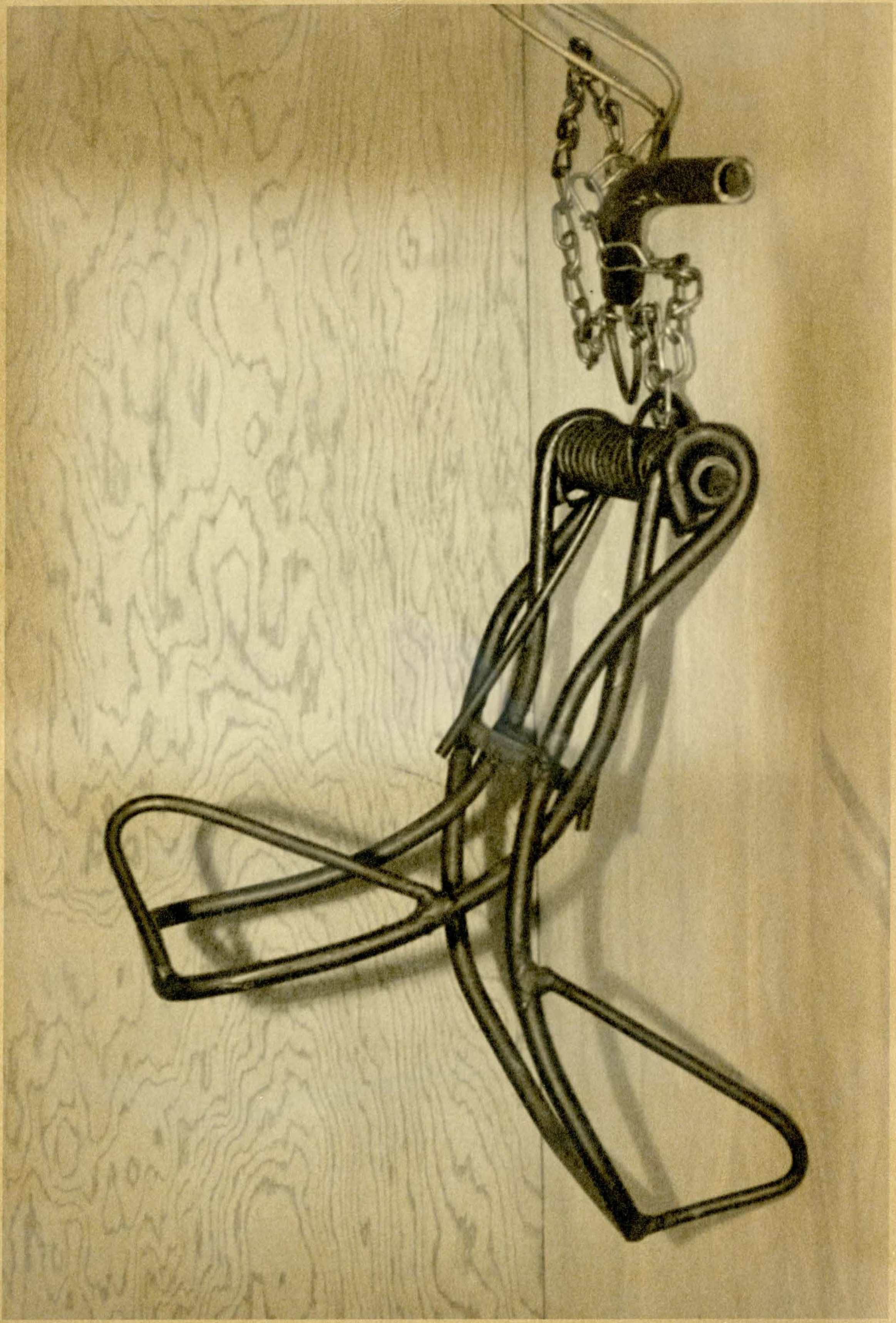
The trap consists basically of two jaws, approximately 10.0 inches wide and made of 0.315 inch diameter wire, which are mounted on an axle. A coil spring wound around the axle powers the mechanism and rotates the jaws.

The trigger is a curved bar positioned perpendicular to the jaws which releases the mechanism upon a slight rotation.

Clamping and prying force are measured perpendicular to the straight cross bars at the center of the jaws.

Fig. 3

Canada Trap



TRAP SPECIFICATION AND DATA SHEET

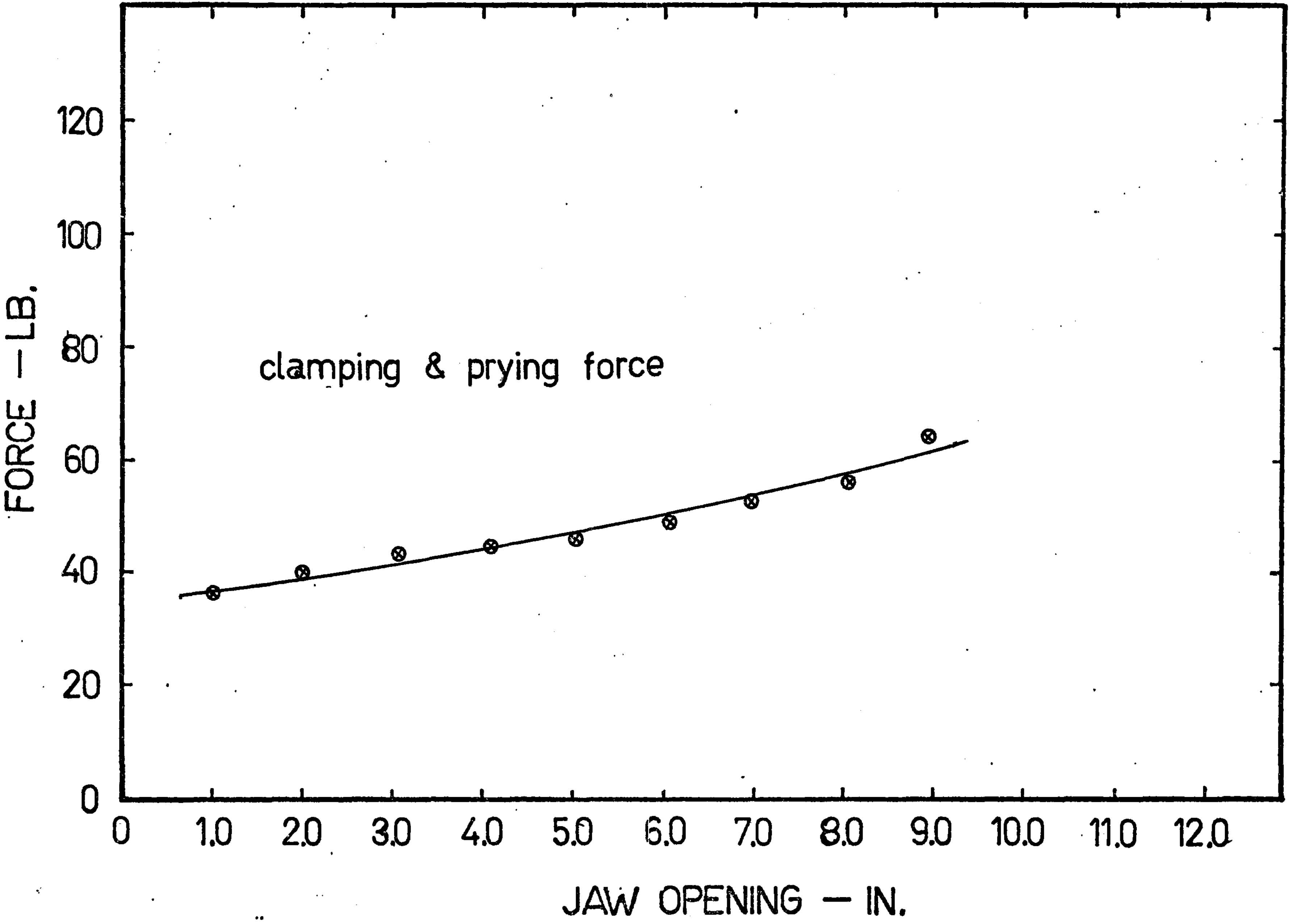
TRAP NAME	Canada Trap
TRAP MODEL	- -
TRAP TYPE	Prototype
SPRING MODULUS	0.9973 in-lb/deg.
MOMENT OF INERTIA	80.131 in^2-lb
WEIGHT OF TRAP	5.2 lb.
EQUIVALENT CONIBEAR MODEL NO.	330
APPROXIMATE HEIGHT (in.)	6.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Canada Trap	Conibear No. 330
MAX.	456.09	351
6"	256.55	304
4"	301.09	351
2"	456.09	277
CLOSING TIME (milliseconds). . (to 2")	57.9	40.5

ENERGY (in.-lb.) BELOW WATER

	Canada Trap	Conibear No. 330
MAX.	111.16	176
6"	111.16	176
4"	62.53	138
2"	27.79	63
CLOSING TIME (milliseconds). . (to 2")	91.7	50.6



THE CANADA TRAP

Comments on the Canada Trap

Being the jaws are curved and an additional straight cross bar is located in the plane where the jaws would contact the animal, the energy developed by the Canada Trap is distributed over a large part of the animal's body. For this reason, although the total energy is high, the energy per unit of contact surface is relatively small.

Of course, zoological research should tell whether a certain amount of impact energy concentrated at one point or distributed over a large part of an animal's body yields similar results as far as humane trapping is concerned.

Comparing the Canada Trap to the "New Conibear Scales", the total maximum energy above water lies just above the Conibear 330. Below water, however, the Canada Trap has a lower energy. Also, its closing time above and below water lies below the Conibear 330.

The trigger bar should definitely be improved. The contact surface between the release bar and the trap wears too quickly and a continuously stable setting is not assured. Heat treatment, the use of a harder material or a reshaping of the contact surfaces would solve the problem.

The trap can strike the animal from the side at the neck and/or heart and lung region all of which are believed to be vulnerable places. Depending on the position of the animal in relation to the trap, it will deliver an effective blow.

The trigger can be located anywhere along the straight crossbar and in this manner allow a variety of trigger positions to suit a particular animal or a particular set.

As far as the overall geometry is concerned, the trap is relatively bulky and not easily stored in a small place. It may be awkward for a trapper to carry a larger number of these traps at one time.

Attention to reduce the number of bends in the bars as well as the welds on the frame could reduce the cost of the trap.

In conclusion, it is believed that the trap has potential and may, after some redesign of the mechanism and elimination of the weak points mentioned, become a useful trap.

F. New Conibear Series

The New Conibear Series consists of three differently sized traps. They are comparable to the previous Conibear Series in the following manner:

Conibear evaluated by Johnston	New Conibear Series
110	110 NC
220	220 NC
330	330 NC

Although the prototype sizes of the 110 NC and 220 NC are larger than the standard Conibear traps, the comparison is valid since these traps are intended for equivalent animal sizes.

The 110-model and the 220-model have undergone substantial changes, whereas the 330 NC-model demonstrates only added features. (See Fig. 4)

All three models will be analyzed in detail and a qualitative optimization will be carried out in PART II. The traps were tested and evaluated for their primary characteristics as they were received and the results are stated on the following pages.

Clamping and prying force are measured perpendicular to the jaws at a point 1.5 inches and 3.2 inches from the axis of rotation for the 110 NC model and the 220 NC model respectively. These points were chosen rather arbitrarily as suitable reference points.

The energy values of the 110 NC and 220 NC on the specification sheets below are compared to the previous Conibear Models 120 and 220 by angular displacement, rather than by jaw opening. This is necessary due to the new shape of the frames. The following data shows the correspondence between linear displacement and angular displacement for the jaw opening of the 120 and 220 (2 spring) models:

Conibear 120

4.0 inches is equivalent to 48 degrees
2.0 inches is equivalent to 114 degrees

Conibear 220 (2 springs)

6.0 inches is equivalent to 53 degrees
4.0 inches is equivalent to 98 degrees
2.0 inches is equivalent to 133 degrees

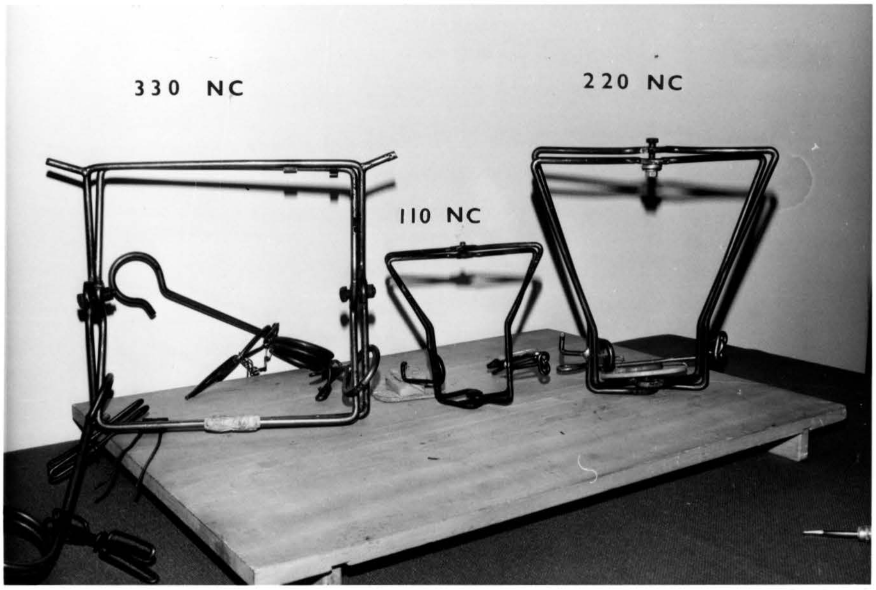


Fig. 4

The New Conibear Series

Emphasis is on frame configuration, therefore the springs of the 110 NC and the 220 NC are not shown.

TRAP SPECIFICATION AND DATA SHEET

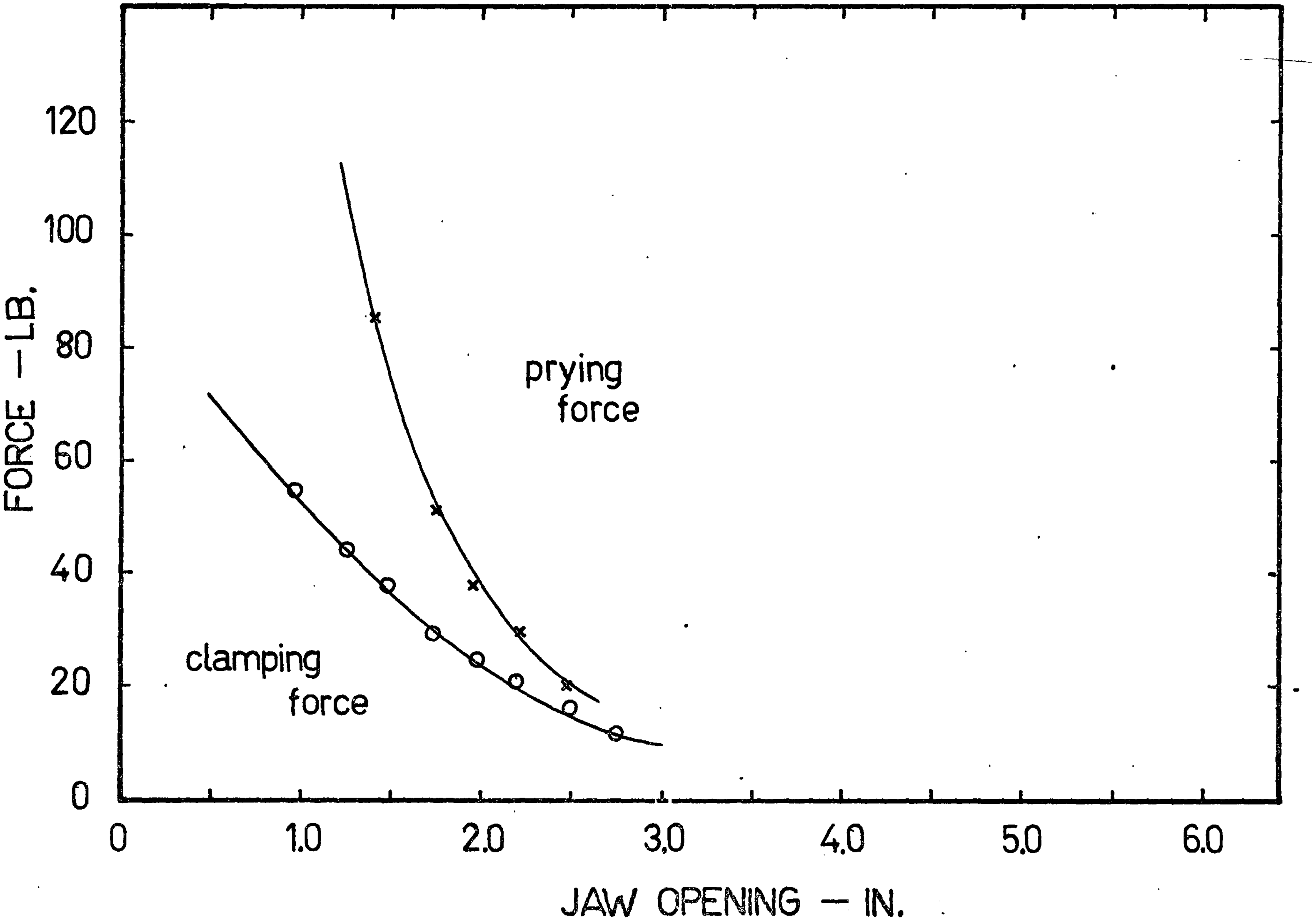
TRAP NAME	New Conibear
TRAP MODEL	110 NC
TRAP TYPE	Prototype
SPRING MODULUS	3.756 in-lb/deg.
MOMENT OF INERTIA	1.169 in^2-lb.
WEIGHT OF TRAP	1.4 lb.
EQUIVALENT CONIBEAR MODEL NO.	- -
APPROXIMATE HEIGHT (in.)	7.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Conibear 110 NC	Conibear No. 120
MAX.	99.0	31.5
4"	20.5	20.6
2"	82.0	31.5
CLOSING TIME (milliseconds) (to 2")	22.9	17.7

ENERGY (in.-lb.) BELOW WATER

	Conibear 110 NC	Conibear No. 120
MAX.	40.12	17.04
4"	7.37	9.2
2"	29.48	13.06
CLOSING TIME (milliseconds) (to 2")	27.8	19.8



NEW CONIBEAR 110 NC

for picture of 220 NC

see page 33

TRAP SPECIFICATION AND DATA SHEET

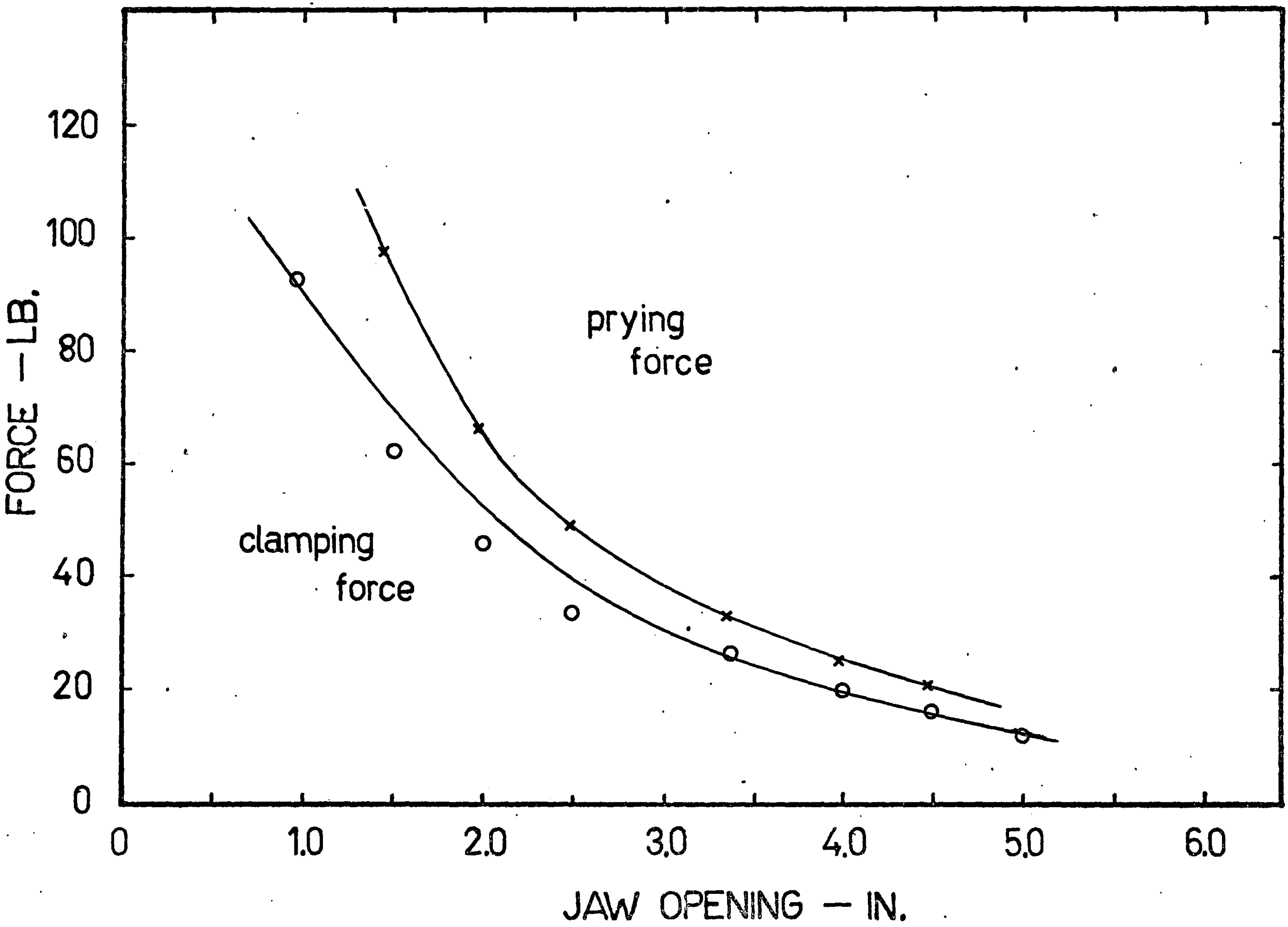
TRAP NAME.	New Conibear
TRAP MODEL	220 NC
TRAP TYPE.	Prototype
SPRING MODULUS	11.66 in-lb/deg.
MOMENT OF INERTIA.	9.559 in^2-lb
WEIGHT OF TRAP	3.7 lb.
EQUIVALENT CONIBEAR MODEL NO.	- -
APPROXIMATE HEIGHT (in.)	11.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Conibear 220 NC	Conibear No. 220 (2 springs)
MAX.	174.18	155.0
6"	56.88	56.69
4"	127.97	98.82
2"	174.18	154.40
CLOSING TIME (milliseconds). (to 2")	35.0	25.5

ENERGY (in.-lb.) BELOW WATER

	Conibear 220 NC	Conibear No. 220 (2 springs)
MAX.	41.22	77.0
6"	21.03	32.0
4"	30.28	76.0
2"	41.22	- -
CLOSING TIME (Milliseconds). (to 2")	56.1	37.0



NEW CONIBEAR 220 NC

for picture of 330 NC

see page 33

TRAP SPECIFICATION AND DATA SHEET

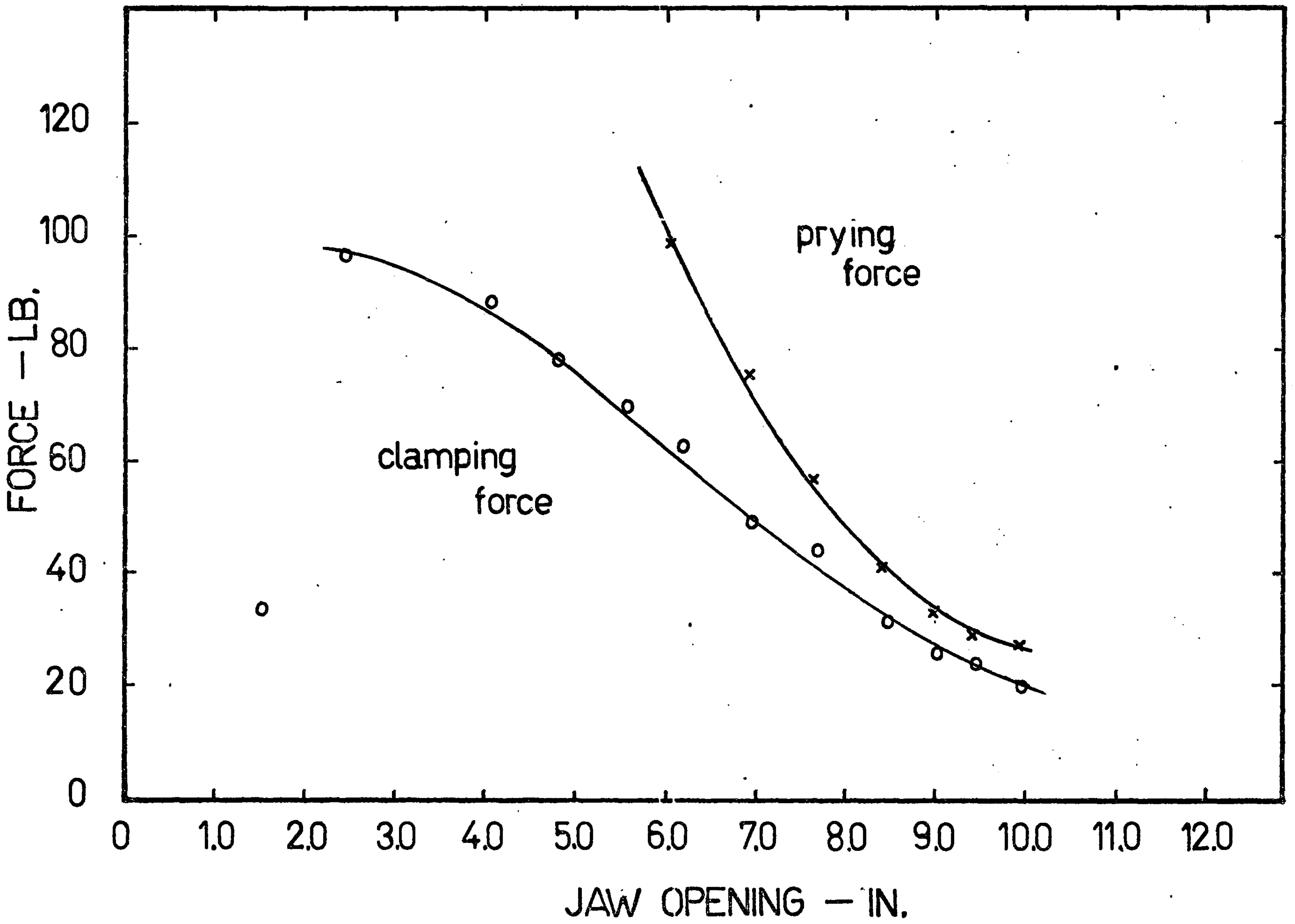
TRAP NAME.	New Conibear
TRAP MODEL	330 NC
TRAP TYPE.	Prototype
SPRING MODULUS	11.77 in-lb/deg.
MOMENT OF INERTIA.	16.36 in^2-lb
WEIGHT OF TRAP	5.25 lb.
EQUIVALENT CONIBEAR MODEL NO.	- -
APPROXIMATE HEIGHT (in.)	11.0 in.

ENERGY (in.-lb.) ABOVE WATER

	Conibear 330 NC	Conibear No. 330
MAX.	460.0	351.0
6"	260.5	304.0
4"	460.0	351.0
2"	460.0	277.0
CLOSING TIME (milliseconds). . . (to 2")	38.0	40.5

ENERGY (in.-lb.) BELOW WATER

	Conibear 330 NC	Conibear No. 330
MAX.	153.0	176.0
6"	98.0	176.0
4"	153.0	138.0
2"	98.0	63.0
CLOSING TIME (milliseconds). . . (to 2")	63.0	50.6



NEW CONIBEAR 330 NC

G. New Jacob Trap

The New Jacob Series consists of three different models which shall be defined in the following manner:

JA I	equivalent to Conibear 110
JA II	equivalent to Conibear 220
JA III	equivalent to Conibear 330

The above comparison to the Conibear traps refers only to the size of the animal intended to be caught in a particular trap. (See Fig. 5) All three models were analyzed in detail and the results of the qualitative optimization is reported in PART II. The evaluation of the primary characteristics of these traps was carried out after the optimization program had been completed, however, the test results have been included in this section so that all evaluation results are listed together.

Clamping and prying force is measured between the tips of the jaws, and perpendicular to them.

Due to the total dissimilarity in configuration between the Conibear and the Jacob Traps no meaningful comparison of energy values at various jaw openings can be carried out. For that reason only the experimentally obtained energy values from the Jacob Traps measured at various heights during the motion of the trap have been stated. The heights are measured between the center of rotation of the jaws and the bottom of the trap.

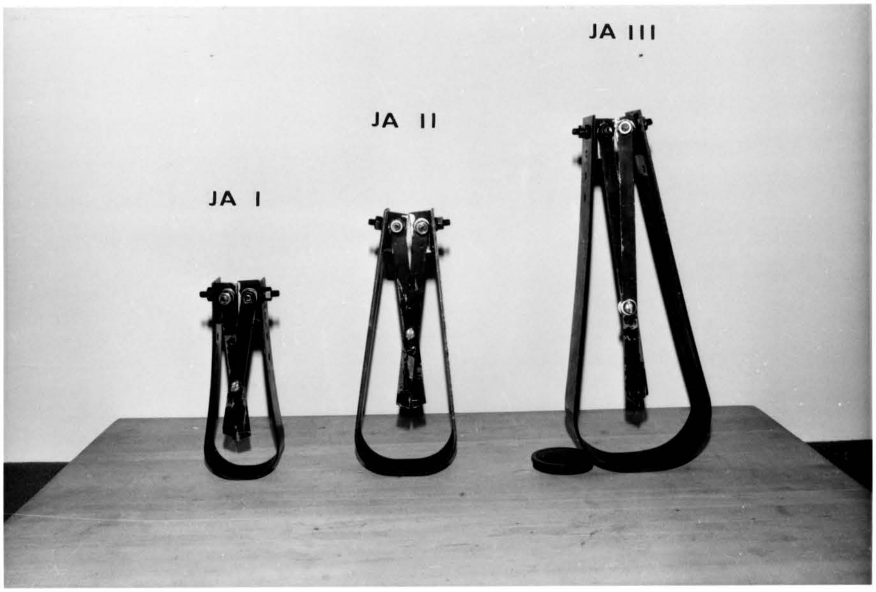


Fig. 5

The New Jacob Trap

TRAP SPECIFICATION AND DATA SHEET

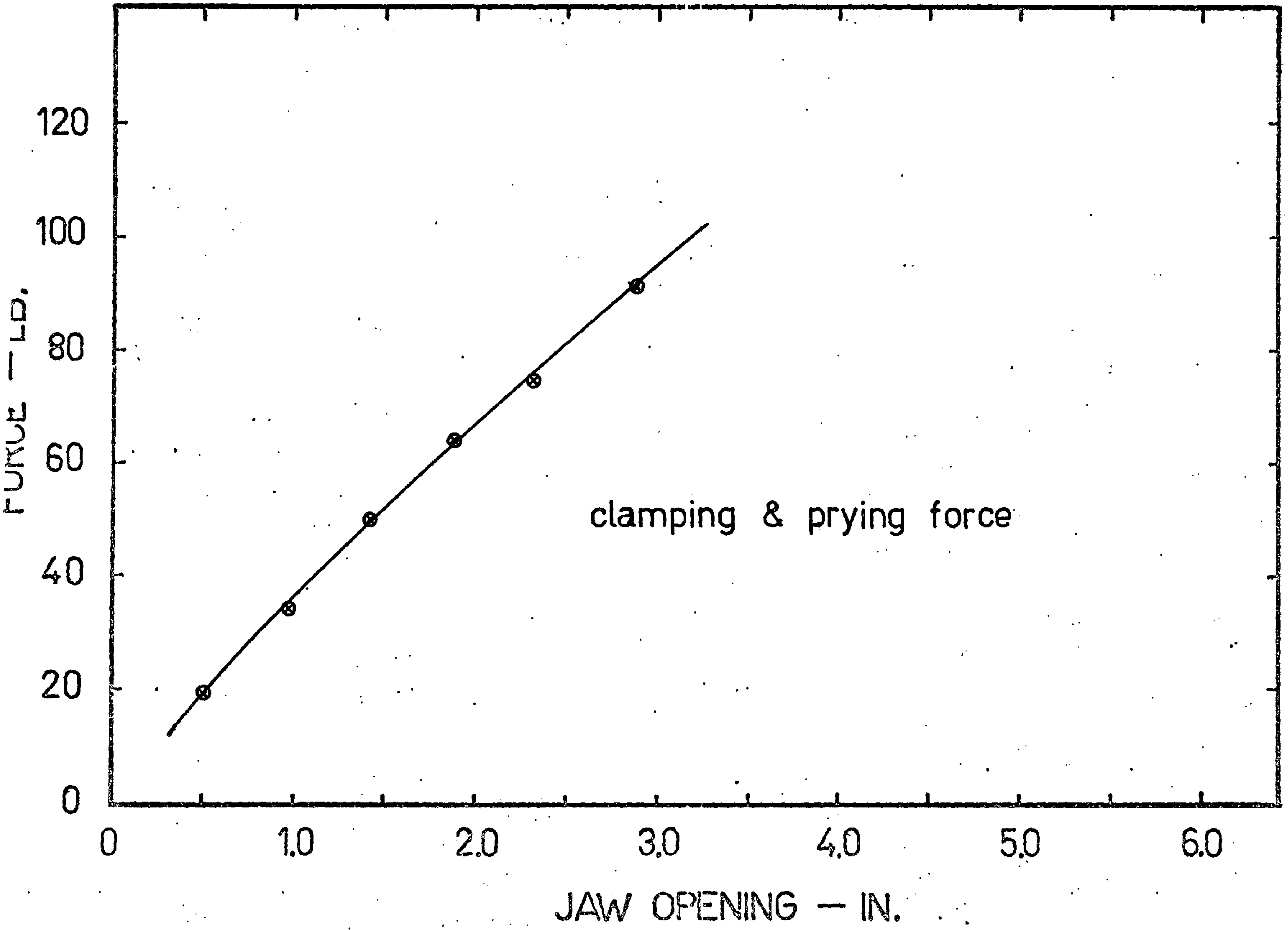
TRAP NAME	New Jacob
TRAP MODEL	1
TRAP TYPE	Prototype
SPRING MODULUS	6.0 lb/in
MOMENT OF INERTIA	3.036 lb-in^2
WEIGHT OF TRAP	0.8 lb.
EQUIVALENT CONIBEAR MODEL NO.	110
APPROXIMATE HEIGHT (in.)	5.8 in.

ENERGY (in.-lb.) ABOVE WATER

	JA I
MAX.	83.27
4"	36.0
3"	47.0
2"	- -
CLOSING TIME (milliseconds) (to 2.3")	14.4

ENERGY (in.-lb.) BELOW WATER

	JA I
MAX.	23.09
4"	2.6
3"	11.8
2"	2.4
CLOSING TIME (milliseconds) (to 2")	26.1



NEW JACOB TRAP JA I

for picture of JA II

see page 43

TRAP SPECIFICATION AND DATA SHEET

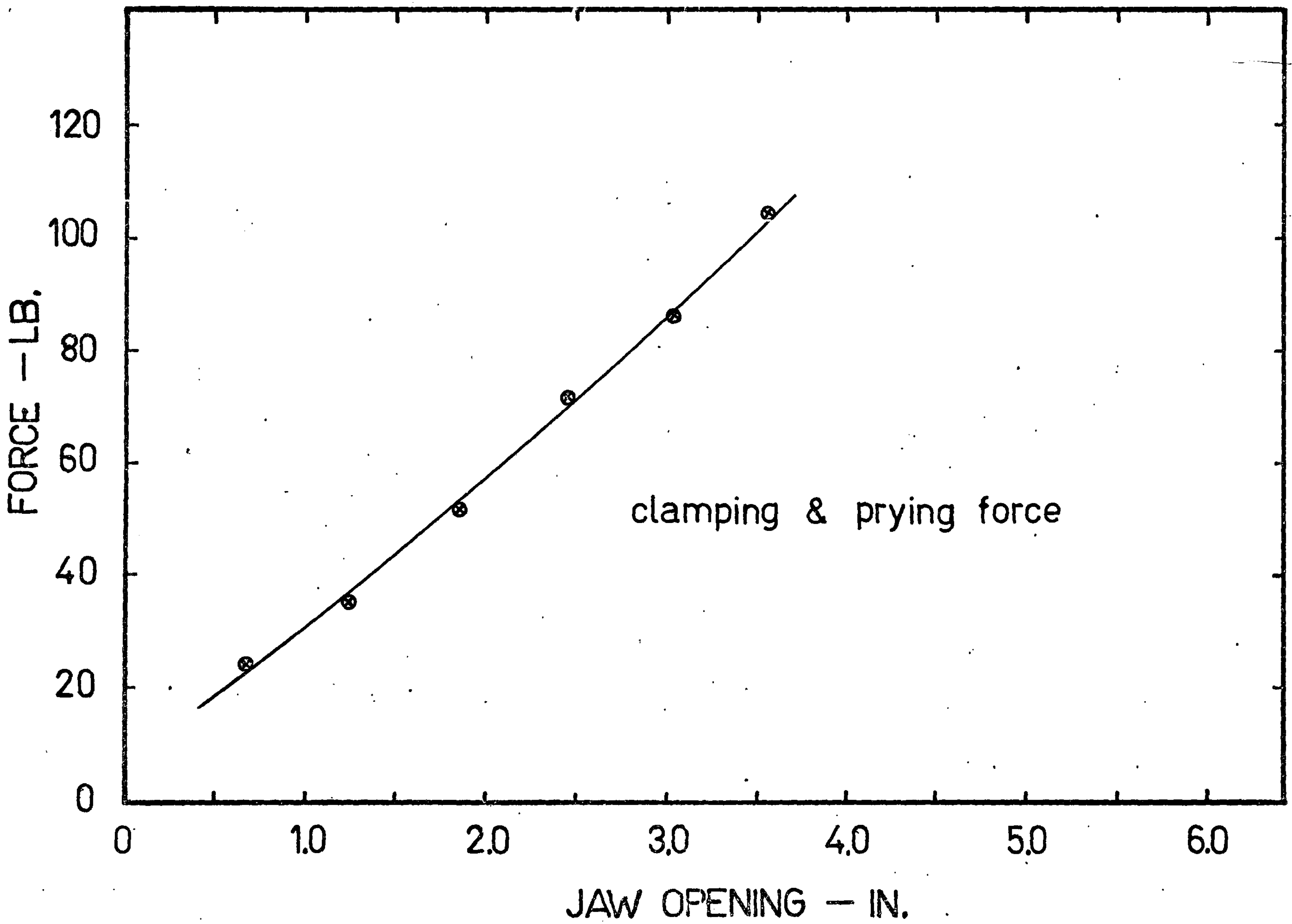
TRAP NAME	New Jacob
TRAP MODEL	2
TRAP TYPE	Prototype
SPRING MODULUS	9.375 lb/in
MOMENT OF INERTIA	12.026 lb-in^2
WEIGHT OF TRAP	1.5 lb.
EQUIVALENT CONIBEAR MODEL NO.	220
APPROXIMATE HEIGHT (in.)	8.0 in.

ENERGY (in.-lb.) ABOVE WATER

	JA II
MAX.	197.24
7"	7.0
5"	143.0
3"	- -
CLOSING TIME (milliseconds) (to 3.8")	19.6

ENERGY (in.-lb.) BELOW WATER

	JA II
MAX.	40.16
7"	2.0
5"	25.0
3"	- -
CLOSING TIME (milliseconds) (to 3.8")	30.4



NEW JACOB TRAP JA II

for picture of JA III

see page 43

TRAP SPECIFICATION AND DATA SHEET

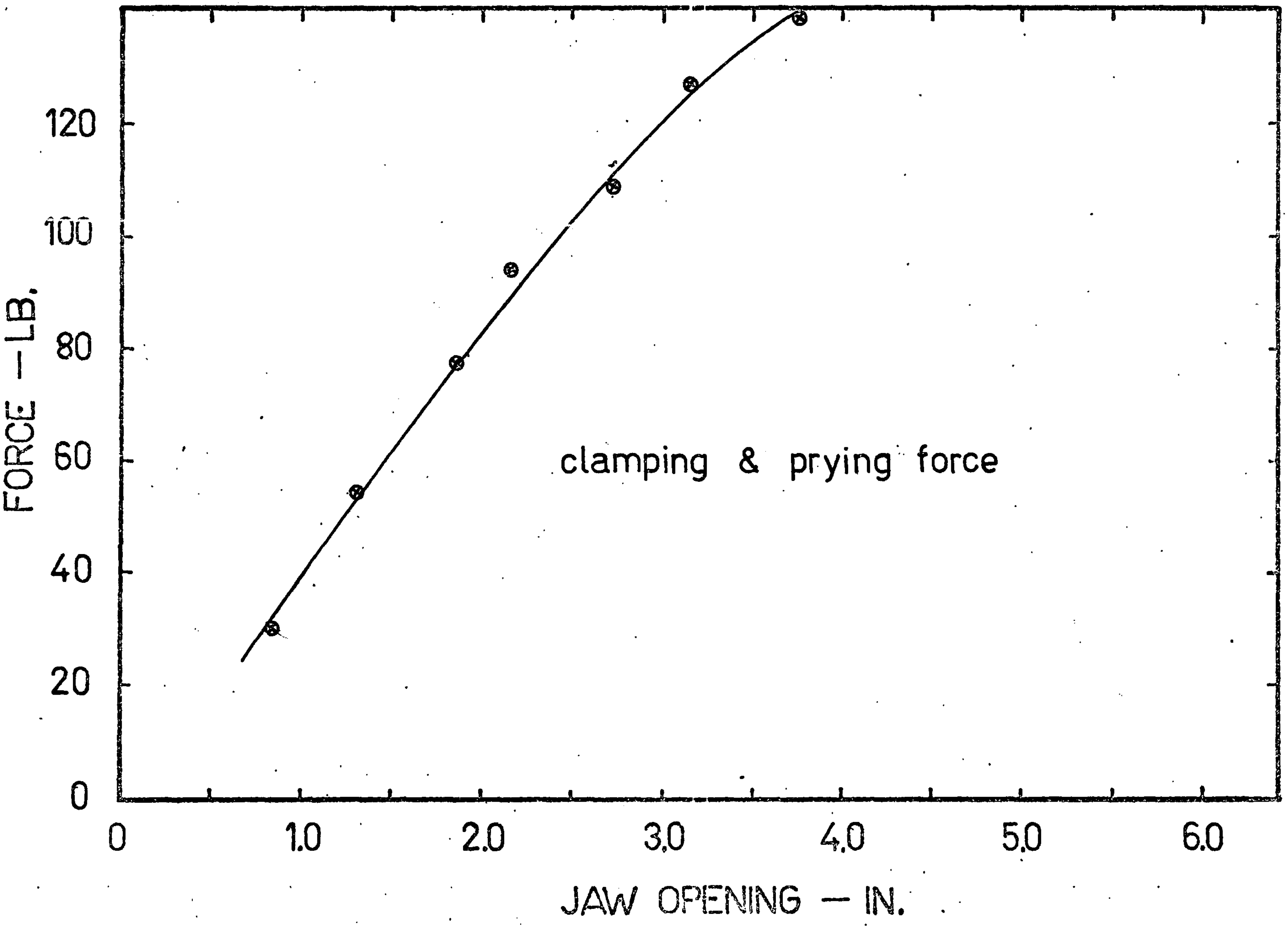
TRAP NAME	New Jacob
TRAP MODEL	3
TRAP TYPE	Prototype
SPRING MODULUS	7.92 lb/in
MOMENT OF INERTIA	45.93 lb-in^2
WEIGHT OF TRAP	2.75 lb.
EQUIVALENT CONIBEAR MODEL NO.	330
APPROXIMATE HEIGHT (in.)	11.0 in.

ENERGY (in.-lb.) ABOVE WATER

	JA III
MAX.	535.09
9"	13.0
7"	194.0
5"	535.0
CLOSING TIME (milliseconds) (to 4.6")	21.2

ENERGY (in.-lb.) BELOW WATER

	JA III
MAX.	87.14
9"	5.2
7"	49.0
5"	84.1
CLOSING TIME (milliseconds) (to 4.5")	40.0



NEW JACOB TRAP JA III

PART II

OPTIMIZATION

CHAPTER I - CRITERIA

A. Introduction

The ultimate goal of the Humane Trap Development Project is to design and build mechanisms which will kill an animal in the most humane way. This means that the animal should meet death with as little suffering as possible. Besides being a humane trap, it must demonstrate other features such as good treatment of pelt, low cost, high safety, etc. These and other points will be dealt with in greater detail later on. All previous evaluation work on this subject has been directed towards obtaining a trap or several traps, which would fulfil these objectives most effectively. Two types of traps were selected as highly promising at the present time and subsequently used in the design and qualitative optimization program. Upon completion of additional research, these traps may satisfy the requirements of the HUMANE TRAP DEVELOPMENT COMMITTEE.

The two series of traps are:

The NEW CONIBEAR SERIES and

The NEW JACOB TRAP

This part constitutes the major emphasis of the thesis project, and deals with the optimization of the above mentioned traps. An attempt was made to systematically analyze every detail of the mechanisms under consideration and to conclude with a set of useful traps.

The problem did not entirely lend itself to a quantitative analysis since it was not possible to apply mathematical models to many of the traps' details. A great number of decisions had to be made on the basis of good judgement and the help of comments from trappers, articles from the literature or qualitative results from previous work done on the project. A further drawback was the fact that the research program at Guelph University did not develop as quickly as expected so that actual data about animals and animal behaviour could not be incorporated in the design of the mechanisms. All available data and trappers' experience was applied where possible.

For these reasons the optimization will be almost entirely qualitative in nature and the author realizes that some statements may be subject to discussion or debate.

B. Optimization Criteria

Before proceeding to the main objective of this project - the optimization program - the criteria to which the optimization work would be subject were evolved. These are as follows in order of importance:

- Animal Control and Point of Application of Impact
- Energy - Mass Ratio and Magnitude of Impact
- Clamping Force
- Closing Speed
- Trigger and Trigger Systems
- Setting and Safety
- Cost of Production

1. Animal Control and Point of Application of Impact

It has become clear that it is possible to design and build a mechanism, which is strong enough to render the animal for which it is intended unconscious and to cause death before consciousness is regained. This fact can be justified by all the animals that were trapped and died very shortly thereafter.

An interesting incident that will support this point further took place in 1971 in British Columbia. Mr. Joe Kardy, president of the B.C. Trappers Association reported that on two separate occasions brown bears were caught in a Conibear 330 and killed instantly in at least one of the cases, since there was no sign of a struggle as one would expect from a wounded bear.

Realizing this, one becomes aware that it is not sufficient to have what appears to be a powerful mechanism, but also, the animal must be in the correct position in relation to the trap at the moment the trap is triggered. Therefore, it is believed that animal control and point of application of impact are the main criteria in all trap design. Concrete data as to the most vulnerable parts of an animal's body are not yet available. However, sufficient evidence from experienced trappers shows that the heart and lung regions as well as the neck and the skull are normally vulnerable parts and these areas are likely those which would lead to immediate humane death. Nevertheless, additional animal research would provide vital information as to what is going on in an animal's body the moment it is hit and shortly thereafter. For instance, it is important to know whether a blow in the heart region always assures an instant kill or whether the heart can move into the lower chest cavity and permit the animal to suffer for some time.

In any future work this point should receive prime attention, and all aspects of trap design should follow this, particularly since this is the most difficult problem to solve.

2. Energy - Mass Ratio and Magnitude of Impact

With the target energy levels defined, an attempt was made to find an optimum Energy - Mass Ratio, which meant designing a spring which would yield the desired energy with a minimum amount of spring material. Of course, the overall configuration of the spring had to satisfy the geometric proportions of the trap for which it was intended.

Until proper energy values necessary to assure a humane kill are available, target energy levels equal to the established Conibear Scales plus 50% were set by Mr. H. C. Lunn of the Humane Trap Development Committee.

3. Clamping Force

An important criterion in trap design is clamping force. Trappers point out that it is not always possible to kill an animal instantly, especially an animal such as the mink, which is very tough and hard to kill. A humane kill by a blow to the animal's body is further complicated by the difficulty of animal control. One can never be really sure where the animal is located in relation to the trap at impact. For these reasons it is important for a trap to have sufficient clamping force left after impact in order to squeeze the animal to death in a very short time interval.

4. Closing Speed

The closing speed of a trap does not require too much attention at the present time, since according to estimates from previous work and reports from experienced trappers, the closing times of most traps and those under present consideration appear to lie generally well below reaction times of most animals for which the traps are intended. More precise work could be carried out later if results from Guelph University show the necessity to increase closing speeds.

5. Trigger and Trigger Systems

The best trap may be a failure if it has an ineffective or unreliable trigger. In trap design, the trigger must receive as much attention as any other detail of the trap. Two main trigger systems have been used extensively in the past. These are:

- a pan type trigger, and
- a prong type trigger.

Experienced trappers have divided opinions on the use of the two types of triggers. Certain trappers prefer one over the other and vice versa. It seems that depending on the set in which the trap is used, one trigger works better than the other. For example the prong trigger is preferred in a water set since the animal swims through the trap. In a runway set, an animal might think a prong trigger to be an obstruction, and shun the trap, whereas, it would walk over a pan trigger. A further doubt as to the reliability of a prong trigger is animal control. A prong trigger mounted in the vertical direction will release the mechanism always at the same angular position, however, depending on the distance from the center of rotation of the prong to the point of contact by the animal, an animal may be located at various positions in relation to the mechanism. These positions with the animal either too far in the trap or not far enough, may not always be favourable for a humane kill. On the other hand, a point in favour of this trigger is the fact that a movement of the prong requires constant contact with the animal's head or chest and assures that these parts of the animal are, at least to some extent, in the trap.

The pan type trigger has the advantage over the prong type trigger in that the animal will find no obstruction in the trap. Also, it is argued that a constant favourable position of the animal to the trap is assured as soon as the animal places its paw on the pan.

Detailed facts on animal behaviour towards both types of triggers as well as animal control with both triggers would be invaluable in deciding for or against a certain trigger or any aspects of it.

A further desirable feature of a trigger is a sensitivity adjustment, which would allow a trapper to change the force required to depress the trigger. Often one wishes to catch only a certain large animal; it would then be advantageous if the trigger could be set in such a manner that a small animal would not be able to activate the trap.

Finally, a trigger must be reliable. It must work every time it is touched. It must be designed to withstand freezing or accumulation of dirt, leaves and small branches which would in any way interfere with the trigger's operation.

6. Setting and Safety

The larger the trap, the more powerful it becomes; and it is absolutely necessary to provide for sufficient safety features. In most cases the trapper will tension the springs and the trap before positioning it in a suitable set.

As the trapper goes through the procedure of setting the trap it must be assured to a high probability at all times that the trap cannot be triggered accidentally and injure the trapper. After the trap has been placed correctly, the last operation should be the setting of the trigger mechanism to the firing position in a safe way, and with a minimum of effort. A trap should also be simple to set; it should not have any complicated or time consuming features for setting.

7. Cost of Production

Throughout the analysis and design work an important factor must constantly be taken into consideration; this factor is the cost of the trap to the trapper as well as replacement parts which might occasionally be needed. If the trapper cannot afford to purchase a certain trap, although it may well be efficient and humane, he will retain his old traps or purchase less expensive ones which may not compare to the performance of a humane trap. This of course would defeat the entire purpose of the Humane Trap Development Program.

8. Secondary Criteria

Additional points had to be taken into consideration.

Bulk and Weight - A trapper often has to carry, or in some way transport, a large number of traps at one time. For this reason a trap should be as light as possible and should be easy to fold up and pack.

Treatment of Pelt - A trap optimized according to all previously mentioned criteria would be useless if it would puncture, tear or otherwise mutilate the pelt, since, in most cases the animal is trapped for the value of its pelt. Therefore, care had to be taken that all parts of the trap that could conceivably contact the animal are well rounded off and have no sharp edges or other points protruding from the mechanism.

Reliability and Durability - It is extremely important to consider the environment in which the trap must work. It is exposed to all weather conditions; it is used on land and in the water. Therefore all joints or moving parts of the trap must be very loosely fitted so that dirt, leaves or snow and ice cannot restrict its motion.

Also, the trap must be built sturdily enough to withstand the rough treatment it will receive.

CHAPTER II - OPTIMIZATION - CONIBEAR

A. Introduction

The New Conibear Series consists basically of two types of mechanisms. First, the small and the medium size traps have frames which are new in shape, are powered by one spring which is usually located above the trap and the jaws close around a vertical axis of rotation. (See Fig. 6 and Fig. 7) These two traps are equivalent to the previous Conibear models 110 and 220 insofar as they are intended for the same size of animals. The following definition establishes the equivalence to previous models and shall henceforth be referred to in the following way:

Previous Conibear	New Conibear Series
110	110 NC
220	220 NC

The second type of mechanism refers to the large Conibear trap which is basically unchanged from the previous model. (See Fig. 8) It has a square frame, is powered by two springs which are usually located on either side of the frame and the jaws close around a horizontal axis of rotation. Since a few minor changes have taken place, the new model will be defined in the following way:

Previous Conibear	New Conibear Series
330	330 NC

The three traps were received by the Department of Mechanical

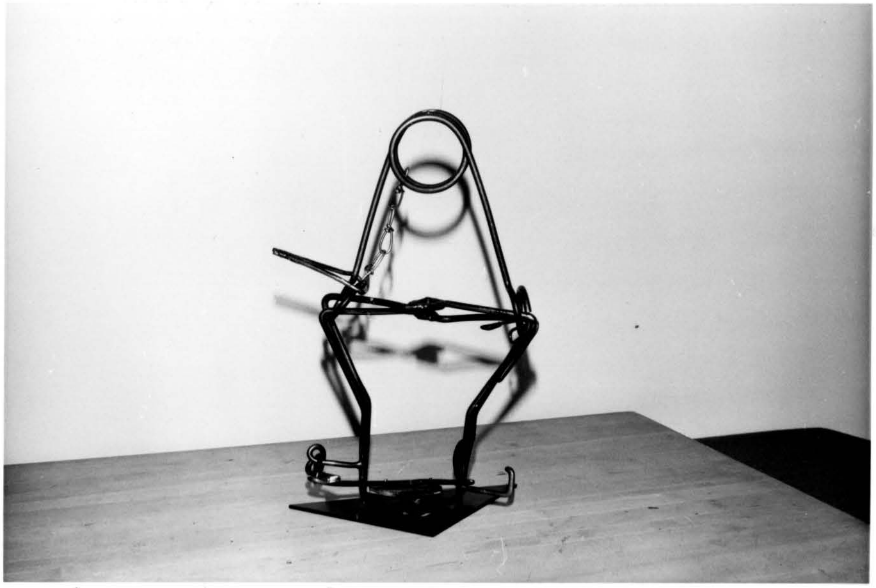


Fig 6

The New Conibear - 110 NC

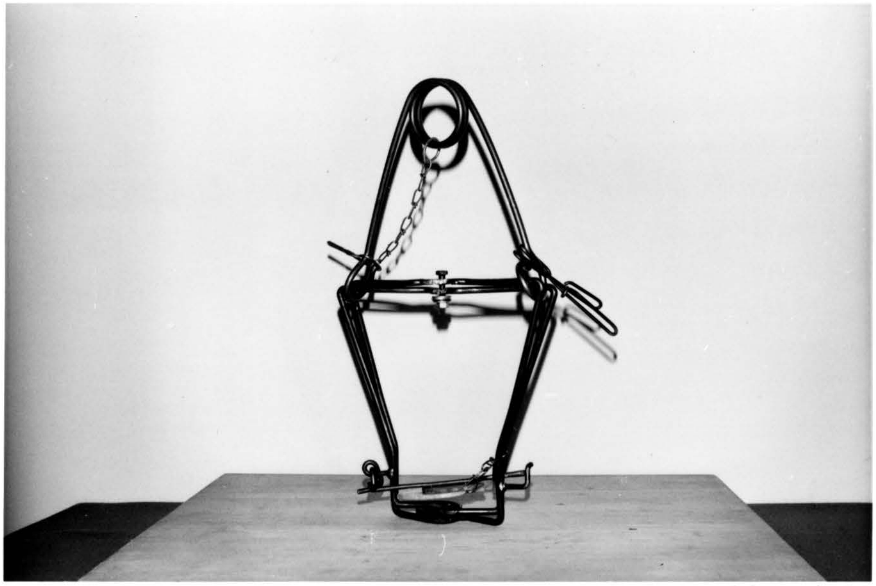


Fig. 7

The New Conibear - 220 NC

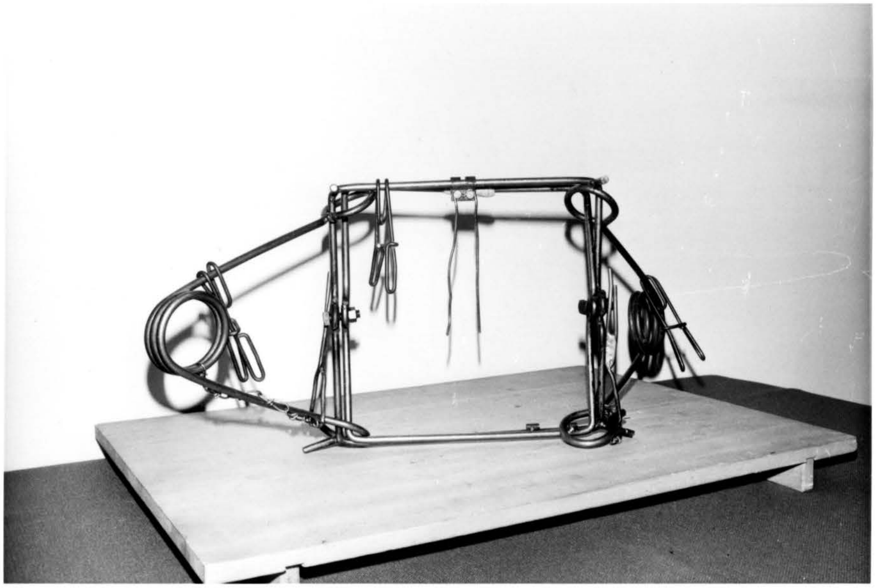


Fig. 8

The New Conibear - 330 NC

Fig. 9

Typical Trapezoidal Frame Shape

Engineering, McMaster University, Hamilton as prototype traps which were already geometrically proportioned, all features of the mechanism from an experienced trapper's and inventor's point of view were well thought out and tested in the field. This is to differentiate from the New Jacob Trap which was received by the Department as a concept of a mechanism to be applied to the development of a prototype trap. The detailed design of this trap had to be worked out, and prototypes manufactured.

The Conibear Trap, as in the past, is a three dimensional trap in that upon being activated, the jaws reach out in front and behind the center of rotation. This is a valuable aspect of a trap concerning animal control, insofar that the position of the animal in relation to the trap is not as crucial, because two sets of jaws can hit the animal's body in two different places. However, the total kinetic energy will be divided accordingly and absorbed in two places, and it is not yet known if this is as effective for a humane kill as the total energy concentrated in one vulnerable spot. Quantitative results from the Guelph research program would be very helpful in anwering this question.

In the following analysis all three traps will be considered simultaneously as the individual features of the traps are investigated. Many of these features are similar, and a separate listing for each trap would produce a lot of repetition.

B. Frame

As mentioned previously, the geometry of the frames of the 110 NC and the 220 NC are similar insofar as the new shape is concerned. The difference lies in their respective sizes, since they are intended for animal groups I and II respectively. The square-shaped frame of the 330 NC is intended for group III. (See APPENDIX D)

Overall Shape of Frame - The new frame shape recommended by Mr. F. Conibear for the 110 NC and the 220 NC is revolutionary in trap design. (See Fig. 9) It demonstrates several advantages which commend it over the previous square-shaped frame in these two sizes. The wider upper part of the trap seems to be more inviting to the animal than a rectangular shaped frame with a constant width equal to that of the lower part of the new trap.

The lower narrow part of the trap helps to control the animal to the extent that due to the small width of access one can predict the position of the animal in relation to the trap with a higher probability. This decreases the problem of trigger design to a great extent.

In animal Group I the mink is the toughest animal and the hardest to kill, and therefore requires special attention. When an animal such as a mink triggers the trap, the lower narrow parts of the rotating jaws will deliver a blow to the vulnerable parts of the animal's body (heart and lung region), whereas the wider part of the jaws, in conjunction with the outward side flare of the jaws, insure clearance for the shoulders and upper rib cage which would offer a greater resistance to the jaws, and thus decrease the effectiveness of the blow.

Animals of Group I which are larger in size than the mink will be caught higher up in the trap. Since these animals will generally have bulkier bodies the wider part of the trap insures that it has a chance to close as far on these animals as on smaller ones caught in the lower part of the trap, thus preserving the same impact energies.

A further feature of the new shape is the increase in clamping force obtained. Due to the greater length of the top end members, the total spring travel has increased which results in an increase in leverage in the lower part of the trap and, with the presently recommended geometric configuration in a mechanical advantage of approximately two. In the upper part of the trap the mechanical advantage decreases, however, it is claimed that larger animals which are caught higher in the trap are not as tough as mink, and the available clamping force should be sufficient.

The loss in clamping force in the upper part of the trap is somewhat compensated by realizing the increase in probability of hitting a vulnerable spot on the animal's body. This increase in probability is due to the fact that the jaws which form an acute angle with the vertical axis upon impact cover a larger part of the animal's body than will the jaws in the lower part of the trap.

The above analysis is valid also for the 220 NC model which is intended for animals of Group II. The basic difference in the frames of the 110 NC and the 220 NC lies in the ratio of the height of the sloping section of the trap to the height of the lower vertical part of the trap. (See Fig. 4) While the ratio of the 110 NC recommended by Mr. Conibear is approximately 1 / 1 the ratio of the 220 NC is approximately 2.5 / 1. Although the total height of the two traps differs, the height of the lower narrow part is the same. The reason for this decision given by Mr. Conibear is that although the 220 NC is intended to catch larger animals, it happens frequently that a mink steps into a 220 NC. The height of the lower part of the traps was kept equal so that the shoulders of the mink are located above the narrow lower parts of the jaws and cannot decrease the effectiveness of a blow to the vulnerable areas of the animal's body. This decision, however, is subject to question since it reduces an essential feature of the trap - its clamping force.

It is believed that ultimately the overall configuration of the 220 NC frame may be altered however, due to lack of quantitative information no justifiable changes can be recommended at this time.

The frame of the 330 NC model is basically unchanged from the 330 model, as is the complete trap. A feature which was recommended by Mr. Conibear is that of welding a stop on the outside of each of the four frame corners to keep the spring loops from sliding around these corners, and along the side of the jaws. (See Fig. 4 and Fig. 10) This is definitely a valuable feature, however it seems that these stops "protruding" from the frame might be very inconvenient in packing and storing the trap, or they may become entangled with other parts which are located close to these stops. Furthermore, welding is expensive and the required four welds might unnecessarily increase production costs.

For these reasons the following alteration is recommended. The frame is slightly reshaped to add four pockets at each end of the spring travel which would accomodate the spring loops and keep them from sliding around the corners. (See Fig. 11) This alteration would not necessitate any welding, but only one additional bend at each corner. Furthermore, the pockets lie in the plane of the frame and would not protrude from the trap.

Upper End Members - This item refers only to the 110 NC and 220 NC and deals with the curved upper horizontal bars along which the spring travels. A model of the upper end members showed that when the upper end members were curved in the manner shown in Fig. 12 the trap closed to 10% of its opening after only about 50% to 60% of the spring travel. This results in an appreciable loss of spring energy because the spring will expand the rest of its travel without doing work on the trap.

For this reason it is recommended to curve the upper end members in the opposite manner, keeping the radius of curvature and all other measurements the same. (See Fig. 13).

To lower the cost of production of joining the two halves of one jaw, it is further recommended to simply bend one end of the frame wire to a complete circle with the inside diameter as required for a

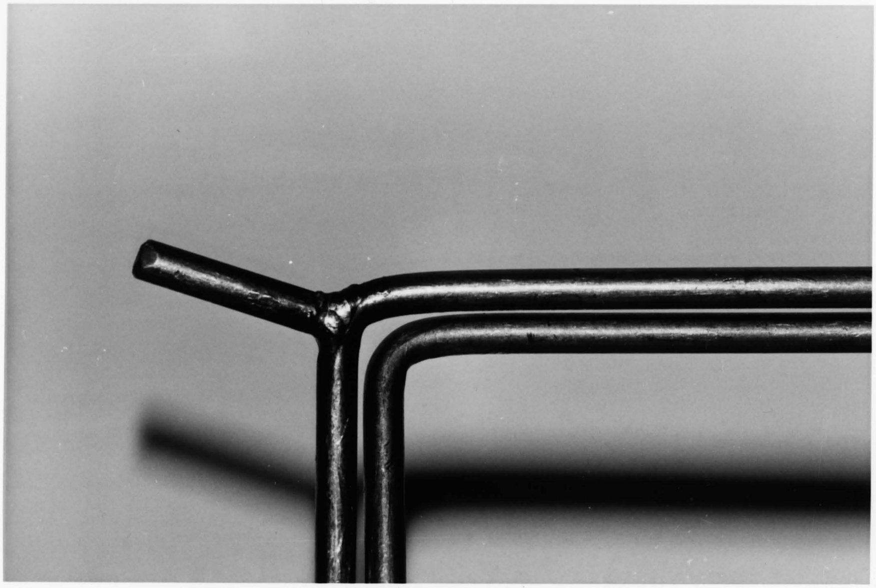


Fig. 10

Close Up of Spring Stop - 330 NC

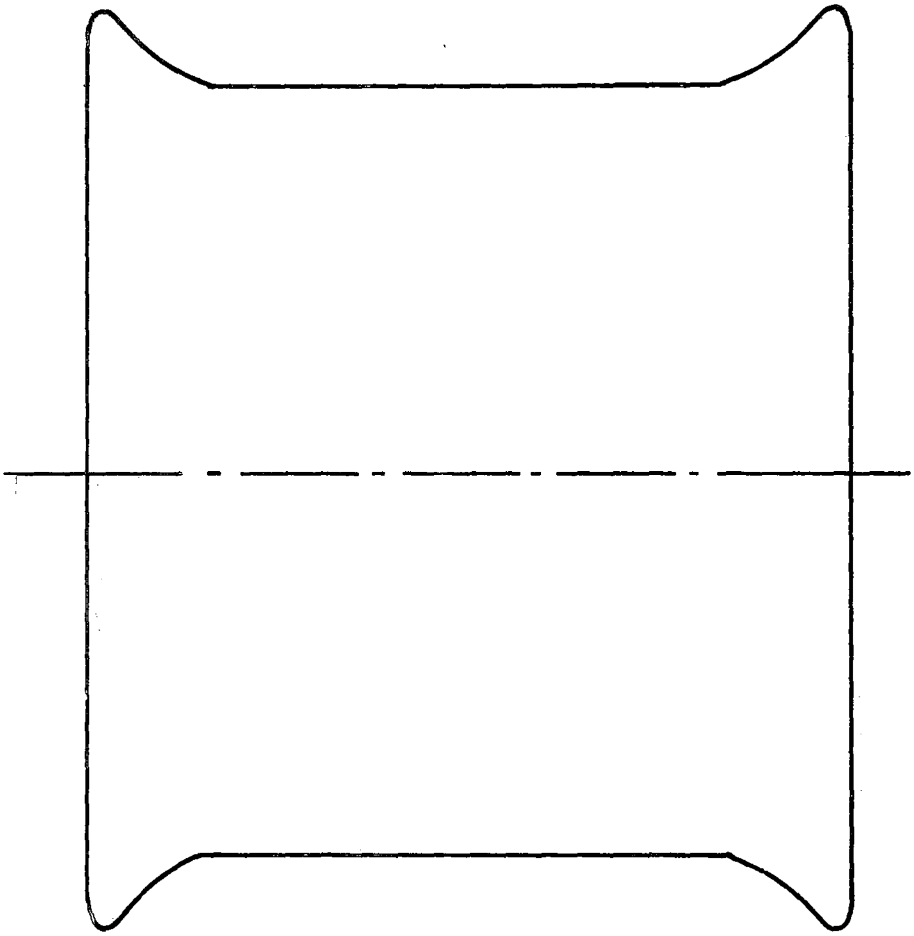


Fig. 11

Schematic of "pockets" on 330 NC frame -

a recommended alternative for spring stops

Fig. 12

Upper end members of trapezoidal frame

(110 NC and 220 NC)

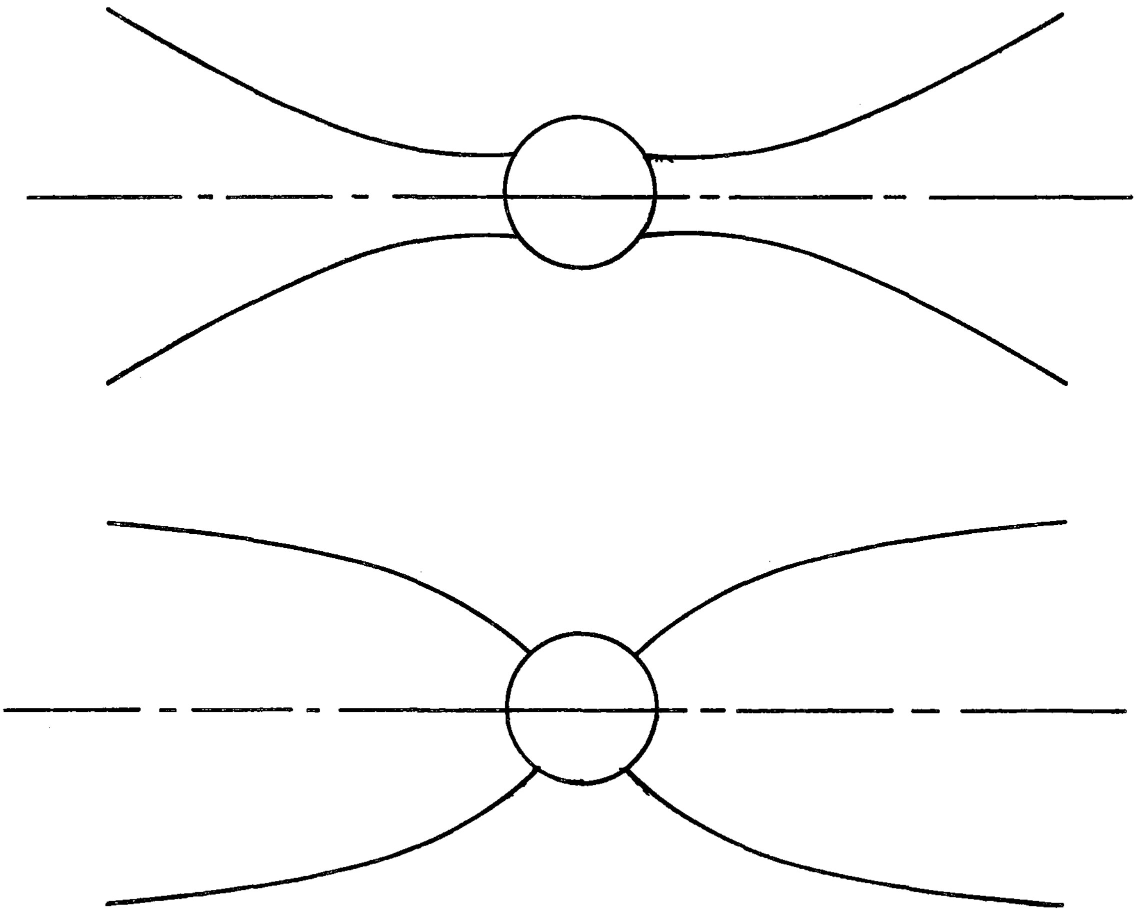


Fig. 13

Schematic outline of upper end members in trap's open position

(110 NC & 220 NC)

Top outline shows present configuration suggested by Mr. Conibear.

Bottom outline refers to the recommended change in configuration.

suitable bolt or rivet, and join the end of the other half of the jaw by welding. The same procedure was followed for joining frame halves of previous Conibear models. This is shown in Fig. 14.

Lower End Members - This item refers only to the 110 NC and 220 NC and deals with the lower horizontal bars.

As mentioned previously under "Upper End Members", these parallel positioned bars which serve as a support for fitting a mounting plate, as recommended by Mr. Conibear should also be altered as outlined before and shown in Fig. 14. This will simplify the manufacture and since two bends become redundant, will lower the cost of production. It will be an easy matter to reshape the mounting to fit this new configuration of the lower end members.

Self Adjusting Jaw Feature - This feature refers to two slots in one jaw in which the pivot pins can move back and forth to allow the jaws of one side to adjust themselves should the jaws on the opposite side be restricted from movement for some reason. (See Fig. 15) This feature works; the adjustment of the jaws however is restricted to the length of the slot in which the pin moves minus the diameter of the pin. Since the length of the slot is quite limited it is questionable whether one set of jaws would close tightly enough on a vulnerable spot of the animal's body, while the other set is kept open by a part of its body that resists being crushed.

Furthermore, should a small animal get caught by the neck (which has only a narrow cross section) in only one set of jaws, the

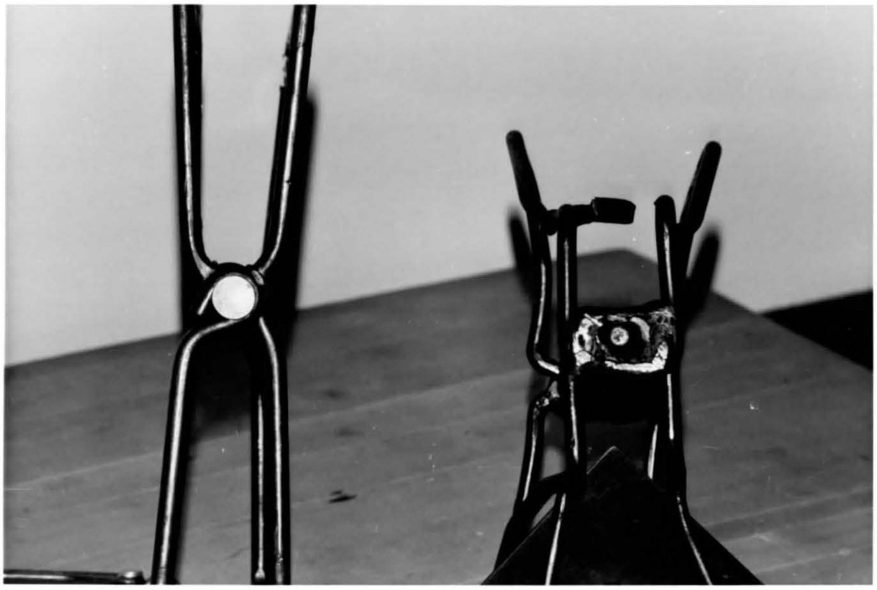


Fig. 14

Joining of frame halves for production purposes

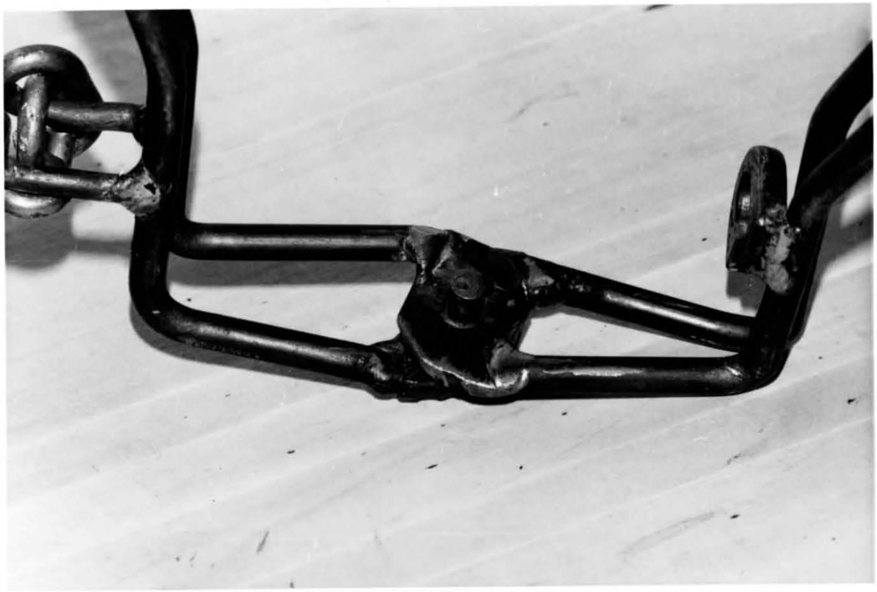


Fig. 15

Self adjusting Jaw Feature

other set might close empty, taking up one-half of the clamping force. Due to that loss, the trap may not be strong enough to choke the animal to death, in which case this feature defeats the purpose of a humane trap.

Finally, the slots would increase manufacturing costs which is undesireable in any case. It is therefore recommended not to include the self-adjusting jaw feature in any of the New Conibear models.

Alternate Frame Shape - A problem that might be experienced with the new frame is that larger animals than those for which it is intended could get caught in this trap. Their body size would not allow the trap to develop adequate energy and clamping force and therefore a humane kill may not be assured. Furthermore, in the upper half of the trap, the squeezing force declines toward the top of the trap. To overcome these problems an alternative would be to extend the vertical lower bars of the frame to the full height of the trap with only enough room for the spring loops to slide along the upper end members. The frame would then have the shape of an inverted top hat. (See Fig. 16) The disadvantages of such a shape would be a restricted application due to a limited animal size range. Subsequently additional trap sizes would be necessary. However, at the present time three different sizes are already provided for and two more sizes, one smaller than the 110 NC and one larger than the 330 NC are under consideration to further increase the size range of animals to be caught by a humane trap. Additional sizes would be impractical from the users point of view because he would have to invest in more traps. Furthermore, this

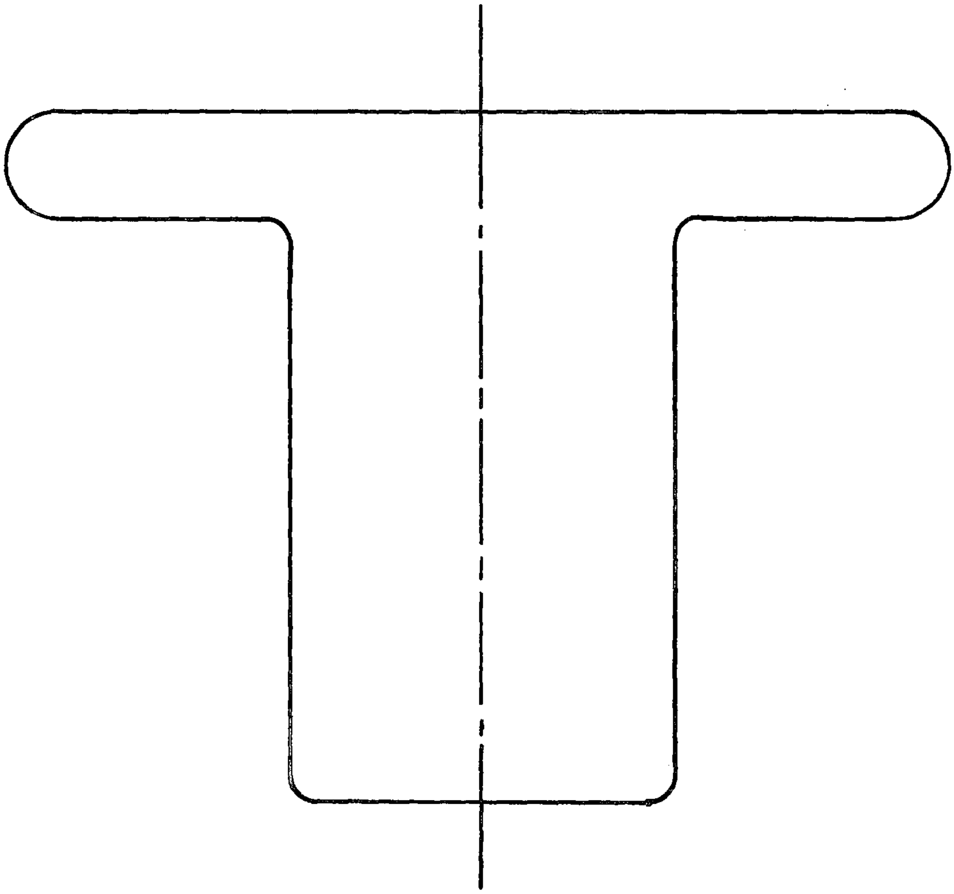


Fig. 16

Schematic Outline of Inverted Top Hat Shape Frame trap loses a possible advantage of a pincer-action to the lower section of the rib cage, while at the same time leaving the spinal, more resistive area of the body, unclamped.

Finally, the trap loses the larger upper visual area which will most likely be more inviting to an animal than the respective narrower vertical bars. It is, however, recommended to investigate this configuration further as soon as results from Guelph University become available.

C. Springs

. Because the spring is the energy source for the trap it requires special attention. It is desireable to have a spring which, when fully deflected, will store as much potential energy as possible with a minimum amount of spring material. Furthermore, it is important to design a trap spring so that as much of its energy as possible is utilized in the trap's mechanism. This means that the spring should be able to extend to about 90% of its fully relaxed position along the trap's jaws. For illustration of typical Conibear spring see Fig. 17.

Material - For this project the following factors have to be taken into consideration when choosing a spring material:

-cost of material
-availability of material
-suitability for extreme environmental conditions (temperature,
 corrosion, etc.)
-ability to absorb high working stress for optimum Energy-Mass ratio.

Three basic steels that would be applicable for the intended purpose were considered:

(i) a high carbon steel,
(ii) a chromium alloy, and
(iii) a nickel alloy.

The following table provides some applicable data on these materials:

Material	AISI No.	Base price per 100 lb.	Extra Cost per 100 lb.*	Availability
Nickel Alloy	3140	8.25	3.15	minimum order 90 - 100 tons
	4340	8.25	5.35	order turned down (difficult to make)
Chromium Alloy	5150	8.25	1.05	minimum order 90 - 100 tons
	5160	8.25	1.05	readily available
Carbon Steel	1095	7.80	0.10	readily available
	1070	7.80	0.15	readily available
	1060	7.80	0.15	readily available

All three materials listed above can be worked to obtain a yield stress of 195,000 psi. However, carbon steels are quite brittle at low temperatures, and the probability of spring failure is quite high. Also, the corrosion resistance is low with these materials. The chromium base

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* additional charge for heat treatment to specification

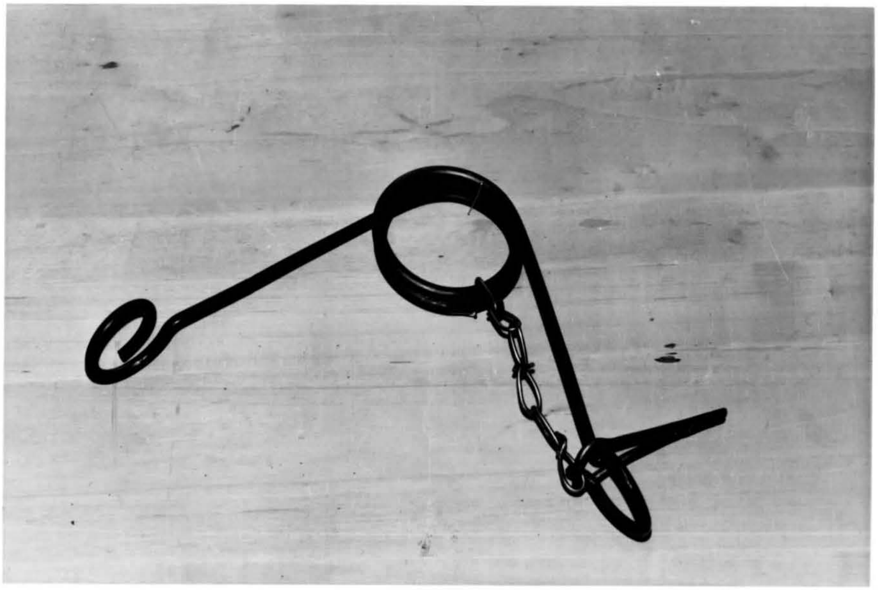

Fig. 17

Typical Conibear Spring

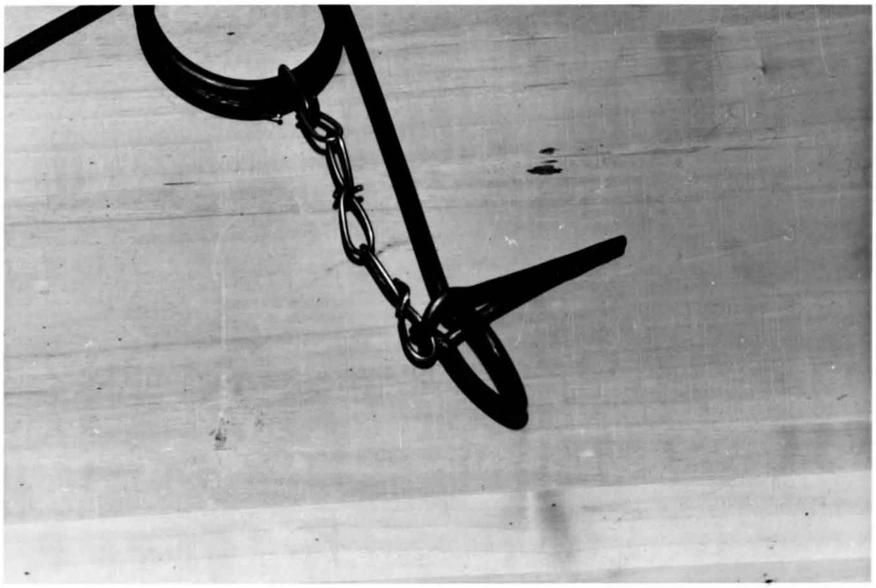

Fig. 18

Spring Release Feature in Engaged Position alloy performs well in the temperature range for which it is intended, and it also has a higher corrosion resistance than the carbon steels. Both the 5150 and the 5160 are recommended with the 5150 having a somewhat larger resistance to impact stress. However, since not too much consideration has to be given to impact stress and 5150 is not as readily available, 5160 is the preferable choice of the two chromium alloys. The nickel alloy also performs very well at low temperatures and has a higher corrosion resistance than the carbon steels. However, the cost of the nickel alloy against the chromium alloy is higher and the availability is lower.

As a result of this evaluation chromium alloy AISI 5160 is recommended for use in this application.

Definitions of Design Variables for Conibear-type Spring

M - moment of the helical coil (in-lb)

T - deflection of helical coil (turns)

k - spring constant (in-lb/deg.)

S - stress (psi)

d - spring wire diameter (in.)

n - number of active coils

D - mean diameter of helical coil (in.)

l - length of moment arm (in.)

A - angle between moment arms when fully extended (degrees)

Energy Levels and Spring Design - The energy values to be obtained from the individual traps are aimed at the values of the previous Conibear

Series plus 50%. These are tentative target figures until definite energy values which are necessary to kill an animal humanely are available.

The tests of the 110 NC yielded results which well satisfy the requirement aimed for. This is true for above as well as below water evaluation. (See page 34). A reshaping of the upper end members, as has been discussed earlier, will further increase the energy range due to increased utilization of the spring energy. The spring which powers the 110 NC, and was supplied by Mr. Conibear, is therefore sufficient and no changes are recommended at the present time.

The test results of the 220 NC yielded a maximum energy of approximately 20% more than the previous 220 model above water, but fell short by about 40% below water. (See page 37). In order to increase the energy of this trap, the following changes are recommended:

- reshaping of the upper end members as discussed before, which will result in a more efficient use of the available spring energy.
- redesign of the recommended spring.

Spring design in this report is based on the formulas developed in Reference (3). The aim was to increase the moment M of the helical coil from approximately 600 in-lb to 800 in-lb.

Since $M = Tk$,

and the linear extension of the moment arms of about 12.0 inches had to be taken into consideration, an 80 degree total deflection of the helical coil was defined, $T = 80$ degrees.

This yielded a spring constant

$$k = M/T$$

$$k = 10.\ \text{in-lb/deg.}$$

The maximum allowable working stress of the material recommended is taken to be

$$S = 180{,}000\ \text{psi}$$

Since $S = 10.2M/d^3$

$$d = \sqrt[3]{10.2M/S}$$

This resulted in a spring wire size $d = 0.356$ inches. The mean diameter of the helical coil can now be calculated. If the number of active coils remains at 2.3 it is found that the mean diameter increases to almost twice the size of the present coil diameter. It is therefore recommended that the active spring length be increased by adding one turn to the helical coil. This results in a number of active coils $n = 3.3$ and a mean diameter of 4.0 inches, an increase of only 1.0 inches over the present configuration. The length of the moment arm $l = 8.0$ inches. This is the distance between the point of tangency of moment arm and helical coil and the center of the loop at the end of the moment arm. 3.3 active coils will form an angle of $A = 70.0$ degrees between the moment arms.

Summary of details of spring recommended for 220 NC

material. . . . . .AISI 5160 (worked for S yield = 195,000 psi)

d . . . . .0.356 inches

D . . . . .4.000 inches

Summary of details of spring recommended for 220 NC (con't.)

n 3.3

l . . . . .8.0 inches

A . . . . .70 degrees

Since $M = F \cdot l = 800$ in-lb
and $l = 8.0$ inches, an increase in force from 65 pounds of the presently used spring to approximately 100 pounds can be expected at the fully compressed position of the spring. Utilizing the stress and deflection formulas for helical coils and calculating the potential energy stored in the fully deflected spring, it is possible to give an estimate of the energy that can be expected from the mechanism. (4)

The energy increase of the 220 NC over the 220 model will be approximately 50% - 75%.

To increase the energy of the 330 NC, which also falls short of the desired energy values, a similar redesign of the spring which is presently used is proposed.

For the 330 NC spring the aim was to increase the moment M from 600 in-lb to 700 in-lb. A total coil deflection of $T = 75^{o}$ was defined. This resulted in a spring constant

$k = M/T$

$k = 9.33$ in-lb/deg.

Again the maximum allowable working stress was taken to be

$S = 180,000$ psi

The following design parameter were obtained for the 330 NC:

material. . . . . .AISI 5160 (worked for S yield = 195,000 psi)
d . . . . .0.341 inches
D . . . . .3.6 inches
n 3.3
l . . . . .9.0 inches
A . . . . .70 degrees

The increase in the length of the spring moment arm became necessary due to the longer spring travel which developed as a result of the "pockets" or spring stops which were added to the frame. The force exerted by the fully compressed spring will increase from about 65 pounds to 80 pounds. The energy to be expected from the 330 NC trap is estimated to be 50% - 75% above the energy level of the 330 model.

The loops at the end of the spring moment arms are to retain their present geometry. The size of the loops of the 110 NC spring and the 220 NC spring is determined by the distance between the outer points of the opposing upper end members in the trap's closed position. The loops of the 330 NC spring are relatively large and the jaws of the trap are open to 3/4 inch upon a fully extended spring. However, one must realize that the animals intended to be caught in the 330 NC are large and have bulky bodies. A tightly fitting spring loop would therefore have no chance to travel far along the frame before the jaws would close on the animal. But this would result in low impact energy as well as low clamping force. Experimental results from both dynamic and static tests on the Conibear Series show that their performance, impact energy and clamping force, increases the further the springs extend along the jaws. This is an important point to consider should any further work on the Conibear Series be necessary.

D. Spring Release Feature

The springs for the Conibear traps are all equipped with an emergency release. (See Fig. 18)

This release consists of one of the loops on the spring being open offering sufficient clearance to engage and disengage the spring from the frame. (See Fig. 19) The opening is restricted during normal trap operation by a keeper. (See Fig. 20) This feature which is recommended by Mr. Conibear serves two purposes. Its primary purpose is to assure a release of the spring in case of an emergency, such as a trapper getting his hand caught in the trap which is accidentally triggered. Secondly, it makes the removal of an animal which is caught in a trap relatively easy. Without the release the removal of an animal from a trap necessitates the tensioning of the spring or springs in order to release the mechanism.

The simplicity of the feature and the advantages pointed out above well commend its use. For the following reason however, it may be necessary to alter the configuration of the keeper. As the trap is triggered it will clear off its mounting and may be thrown to the ground or against any other solid object in the immediate vicinity of the trap.

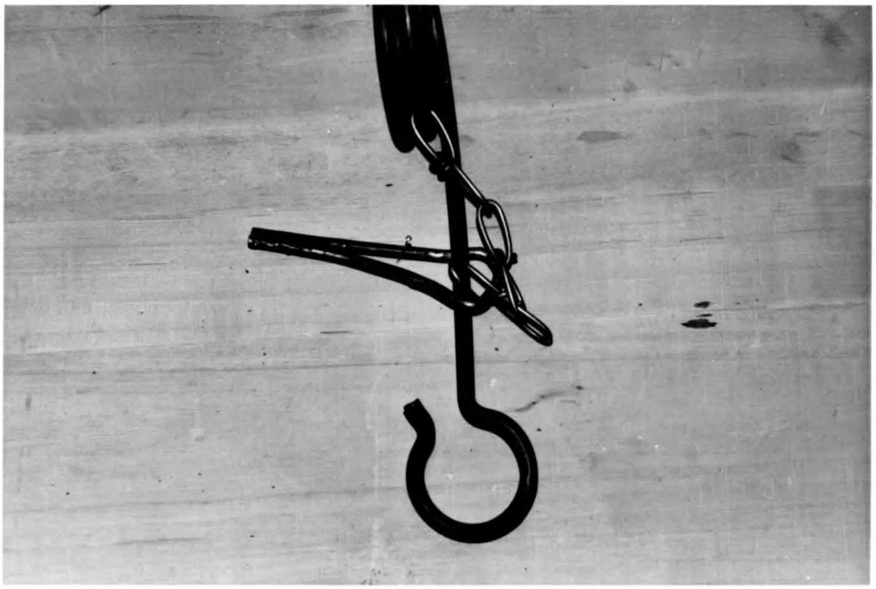

Fig. 19

Spring Release Feature in Disengaged Position

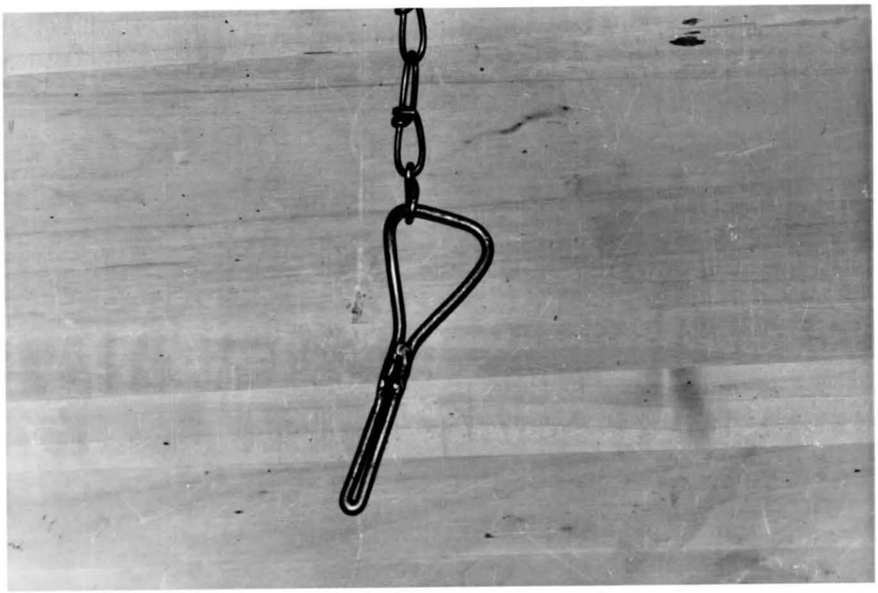

Fig. 20

Keeper of Spring Release Feature

During this time it may happen that the keeper is hit and subsequently released from the spring loop. An additional rotational motion of the spring would then free the spring of the frame and release the animal.

Should the keeper remain on the spring during firing, it is then still possible that the animal in its last struggle will move the trap around disengaging the keeper from the loop and the spring from the frame.

It is apparent that any release which can be removed by pushing on it can release at an undesireable moment, since it may be pushed off by being thrown against a tree, a rock, solid ground or any other solid object. Therefore, a release clamp that can only be activated by pulling on it should be used.

Fig. 21 shows the schematic of a possible solution, however additional work for refinements are recommended.

E. Trigger Systems

As mentioned previously, the trigger is of utmost importance and may mean the success or the failure of an otherwise very effective trap.

The trigger must be simple in design and simple in its use. On the other hand it must be rugged and able to withstand the rough environment in which it has to operate. In designing the trigger mechanism one must always be aware that the trigger has to hold a relatively large

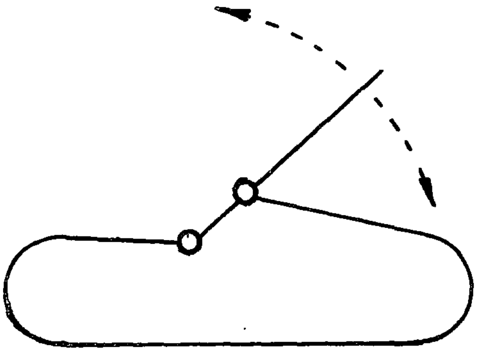

Fig. 21

Schematic Outline of a Clamp type Keeper force, the force which the trap exerts in the set position. To activate the trap, however, only a very small force, the slight touch of the respective animal's paw or head, must release the trigger. The trigger must also be reliable, it must work every time. Finally, a trigger mechanism must be inexpensive to manufacture to keep the overall cost of the trap at a minimum.

There are two basic types of triggers in general use, as outlined before. These are:

- a pan type trigger which is activated when the animal places its paw on it, and
- a prong trigger which releases the trap as soon as the animal pushes its head or body against it.

General comments on both triggers have been outlined before and need not be repeated at this point. Their application to the Conibear Series, however, will be discussed in detail.

The Prong Trigger - The traps under consideration are not only used on land but also in a lot of water sets. In water sets the trap may be totally or partially submerged. Animals that move through the water will do so by swimming or paddling. A pan type trigger would therefore be only of little effect, since the animal would normally not place its paw on it. A possible release of the trap could take place if the animal's paw would accidentally touch the pan trigger. For this reason, and regardless of the short comings which are pointed out in connection with the prong trigger, it is believed that each trap under present consideration should have a suitable prong trigger available. This may not have to be the permanent and only trigger for the trap, however, it is quite conceivable to have a pan trigger as well as a prong trigger fit the same trap. A trapper could then choose the trigger according to the appropriate set. The present Conibear prong trigger with minor modifications lends itself well to an easy replacement.

The objections to the prong trigger have been a possible freezing of the prong mounting to the frame and the uncertainty of the animal's position in relation to the trap. Also, it is speculated that the vertically positioned prong hanging down from the upper part of the trap and being in the visual range of the animal, may be interpreted by the animal as an obstruction.

The overall configuration of the 110 NC and the 220 NC with the narrow lower part lends itself well to optimizing animal control. Due to the narrow passage, one can predict the position of the animal in relation to the center of the trap much better than one could with the previous square shaped frame. Taking this advantage into consideration and mounting the trigger horizontally on a jaw in the lower part of the trap, the animal will contact the prong very near the center of the trap most of the time. (See Fig. 22) This fact will make it possible to estimate the linear displacement of a point on the prong as it goes through a certain rotational motion with a greater accuracy than before. The prongs could be made for various animal sizes insofar as their angular rotation necessary to spring the trap would vary. This can be done by increasing the depth of the slot within the prong holder which accomodates the trigger dog. A deeper slot would require an increased

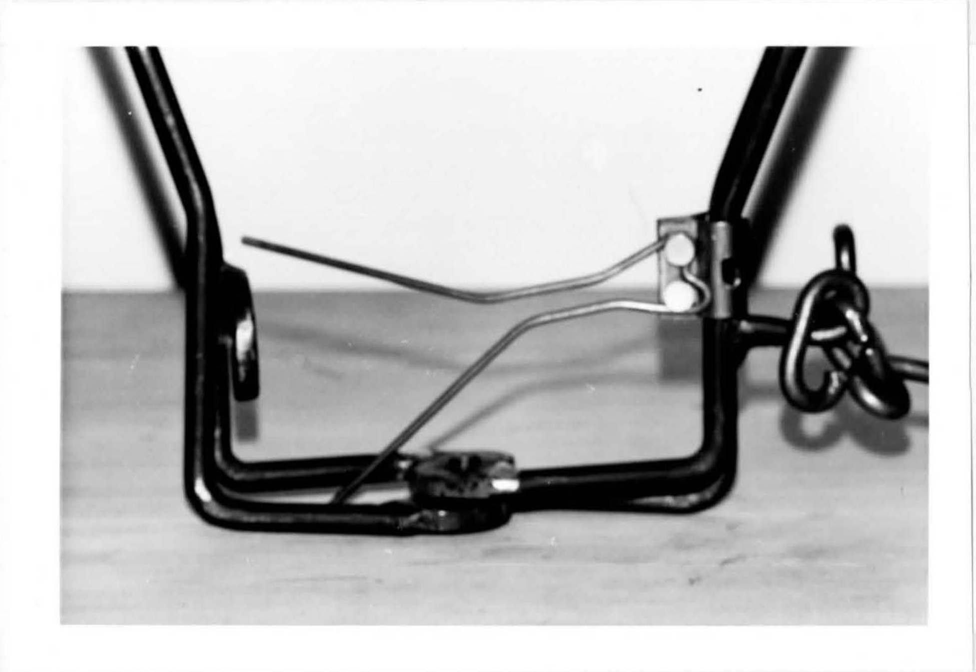

Fig. 22

Prong Trigger Horizontally Mounted

(110 NC and 220 NC)

angular rotation for lifting the dog, and would provide for a larger linear displacement in the longitudinal direction.

The prong mounted in the lower part of the trap would also help to decrease the problem of it being an obstruction within the animal's view. This would especially be true in a set where the trap is partially submerged in the water. An animal swimming through the water keeping its head above water level would not at all see the prong. A further advantage of the prong trigger being mounted in the horizontal position is the height adjustment along the vertical bars. A trapper could set the prong at a height suitable for the animal. A small plastic c-clip which would fit tightly over the material of the frame could hold the trigger in any desired position and keep it from sliding down.

The 330 model has proven itself well in the field and for the present time seems to fulfil its intended purpose. This also applies to the trigger which is the previously mentioned prong type. On all models the problem of freezing between prong mounting and frame can be reduced by the addition of a nylon/teflon coating applied to the inside surface of the prong mounting.

The Pan type Trigger - The following discussion refers only to the 110 NC and the 220 NC. The main criterion in arguing in favour of the pan-type trigger is the improved animal control. It is probable that as soon as the animal places its paw on the treadle, it is positioned well for a humane kill.

Data is needed from live testing to shed more light on this matter, and to show whether or not there exists a justifiable consistency between the position of an animal's paw while placed on the pan and the position of its neck or any other vulnerable spot on its body. In other words, is it possible to predict to a high probability the animal's position in relation to the trap upon having placed its paw on the pan trigger.

The 110 NC and the 220 NC were designed by Mr. Conibear with a similar pan type trigger, differing only in their respective sizes. The mechanism of the trigger system is quite ingenious and several features demonstrate the potential of this pan trigger:

- sensitivity of activating the trigger
- incorporated safety harbour
- ability to set trigger to firing position from outside the trap. (See Fig. 23)

However, in comparing the trigger mechanism with the generally desirable features of a trigger it falls short in

- simplicity of design and configuration
- cost of production.

The present trigger mechanism involves a lot of individual parts which complicates the overall configuration of the trap and increases the cost. The bars which provide the fulcrum and the stop for the pan crossbar stick away from the frame and pose a problem as far as handling or packing is concerned by becoming entangled with items in the immediate vicinity. To decrease the number of parts of

Fig. 23

Pan Type Trigger as suggested by Mr. Conibear

(110 NC & 220 NC)

Trap is held up by a Plastic Mounting

which the trigger is composed, a relocation of the fulcrum and the stop for the crossbar directly on the frame was attempted. However, it was soon realized that if the fulcrum was shifted closer towards the frame than in the present configuration, the force to depress the pan on the side nearest the fulcrum increased substantially since the moment arm had decreased to almost nil. Maintaining the basic configuration (safety harbour, firing face, outside loading), various other means of mounting the crossbar on a simplified fulcrum were investigated, though without success. However, lack of simplicity is not the only disadvantage of the trigger. The cost of producing this mechanism may be relatively high due to:

- a large amount of individual parts involved
- a large amount of bends in the wire material
- joining 3 parts to the frame by welding
- high workmanship necessary in making and fitting all pieces to assure consistent reliable trigger action.

Again it is pointed out that the trigger has definite potentials and although this investigation did not improve Mr. Conibear's trigger concept, it is possible that future efforts might yield a more practical and economical solution.

An alternate pan type trigger which consists of only four parts is described below. The four parts are:

- a cross bar
- a treadle mounted on the cross bar
- a small mounting plate

- a retaining hock mounted on this plate (See Fig. 24) The plate is mounted on one of the vertical jaws in the lower part of the trap pointing toward the opposite jaw in the trap's set position. The hook which is mounted on the plate is situated around this opposite jaw pointing back toward the mounted plate. In this position hook and plate are parallel. The cross bar which has a small bend at one end fits snugly through a hole in the plate and secures the hook from an outward motion. The trap is now set and the slightest pressure on the treadle will release the cross bar from the hook and spring the trap. (See Fig. 25) The trigger does not have a built in safety lock, but a separate lock must be used. Additional work on the trigger is still needed and in any future work this item should be given special attention.

F. Safety Lock

As the trapper goes through the procedure of setting the trap, one of his first activities will be the tensioning of the spring or springs. To continue with the setting, it is necessary to hold the spring in the compressed position. Previously this function was carried out by a simple hook made of steel wire. This hook, however, had the disadvantage in that it could slip off the spring during the setting of the trap. To overcome this problem, Mr. Conibear suggested a spring safety lock which could be locked after it had been applied to the spring and could only be released by unlocking it in a fashion similar to a safety pin. This lock serves its intended purpose very well. An alternative to this lock with a simplified configuration would be a

Fig. 24

Recommendation for modified Pan type Trigger.

Trigger in Set Position

Fig. 25

Trigger in Release Position

combination of the old hook and the safety lock suggested by Mr. Conibear. (See Fig. 26) The hook would retain the elongated hole at one end to allow for sufficient movement during the tensioning of the spring and frame as well as for the later removal of the hook. Its other end would be very similar to the old type hook with the difference that the open end is slightly smaller than the diameter of the spring wire. This feature would prevent the hook from slipping off by its own weight, but could easily be removed by the trapper by simply pushing on the hook. This simplified configuration would somewhat decrease the cost of production. (See Fig. 27)

This hook can also be used as a safety device on the frame to insure against accidental firing of the trap. The hook would not be necessary if the trigger safety harbour, which was recommended by Mr. Conibear, would be used. This safety harbour is a part of the pan trigger which was discussed above. If the trigger cross bar is engaged into the safety harbour it is not possible to fire the trap since the trigger is locked. It seems, however, that the hook, although quite unsophisticated, has potentials over other safety features since it is cheaper to produce, simple to use and fulfills well its intended purpose. A further alternative to the hook in securing the frame from turning, would be to hold the frame at the fulcrum. This could be achieved with a sliding bar at the fulcrum which is partially hexagonal and partially cylindrical. Both halves of the frame would then have to be manufactured with an inside hexagon at the axis of rotation. The frame would be locked if the hexagon bar were engaged in both halves. A relocation of the bar from the hexagon to the cylindrical part on one side of the

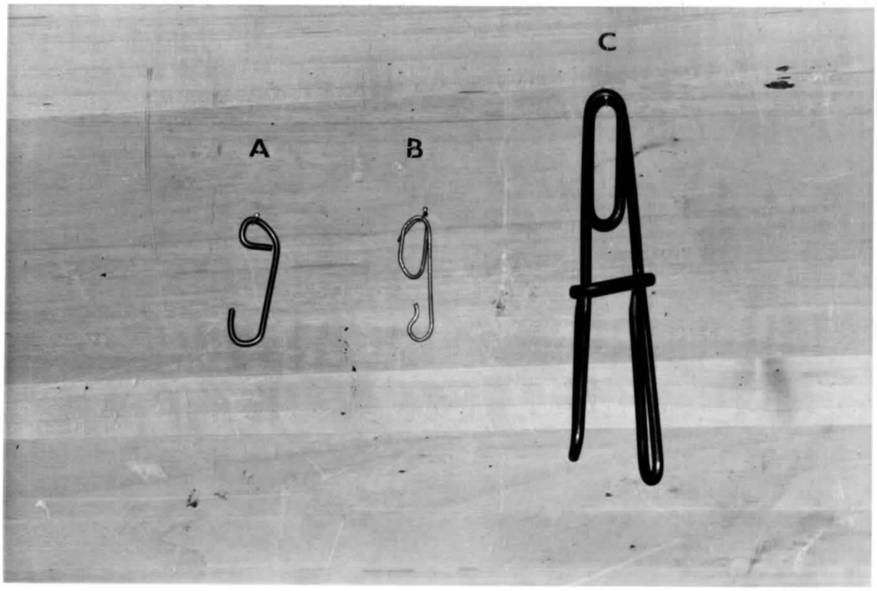

Fig. 26

Safety Hooks - Safety Lock

Previous Conibear (A) - Recommended Modification (B) - Present Conibear (C)

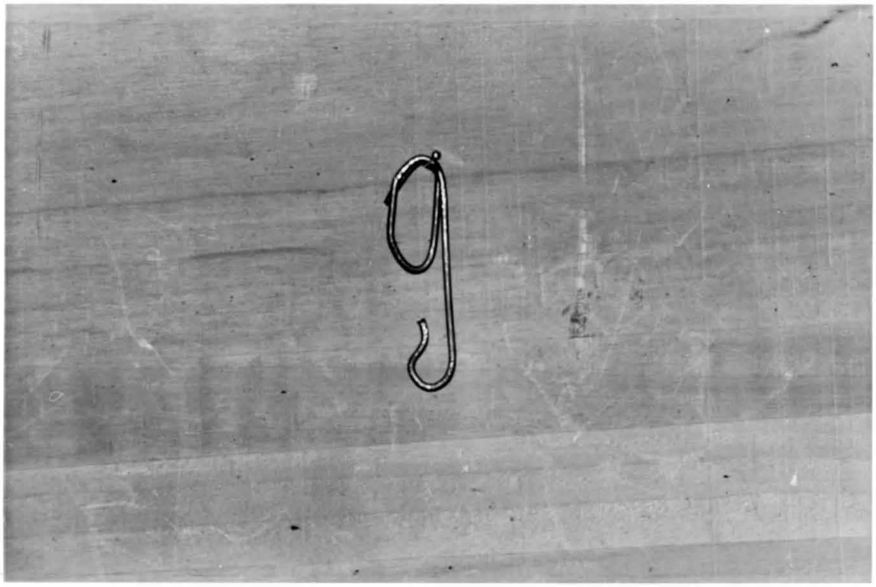

Fig. 27

Safety Hook - Recommended Modification

frame would allow the frame to rotate. The disadvantage of this bar would be that in order to release the bar, the frame would have to be slightly depressed so that the bar can be pushed to the release position. This however, may upset the trigger which was set previously. Also, the hexagon feature will be more costly than the safety hook.

G. Spring Tensioner

The springs used in the Conibear traps are quite strong and this is especially true for the 220 NC and the 330 NC. It is strenuous and tiresome for a trapper to tension these springs with his bare hands, particularly if he is setting a large number of traps at one time.

To assist the trapper in this task Mr. Conibear suggested a spring tensioner, which looks basically like a pair of scissors. It operates by fully opening the tensioner at the handle, engaging small hooks located at the end of the moment arms into the spring loops and then using both hands to close the handles fully. In the closed position one hand can secure both handles while the other can engage the safety hook on the spring. (See Fig. 28)

It seems that there is no real necessity for the safety lock on the spring tensioner since it takes a similar effort to position this safety lock as is done to position the safety hook. The tensioner works quite well and its simplicity in design and configuration commends it.

There are two recommendations for possible alteration. First, since the tensioner is relatively large it becomes quite heavy and it may be a bit of a burden to a trapper who has to carry it. It is therefore suggested to change the material of the tensioner from steel to aluminum. Secondly, it is recommended that the two separate hooks at the end of the moment arms be incorporated into the moment arms themselves. (See Fig. 29) This will reduce the cost of production.

H. Mountings

The 110 NC and the 220 NC cannot be set up without the help of some external mounting device.

Two means of mounting any of the Conibear traps were suggested by Mr. Conibear. A plastic mounting shaped to fit the frame of the traps in a variety of positions makes it possible to not only mount the trap, but make it adaptable to various different sets. The mount can hold the trap on a vertical, horizontal or even an inclined support. This mount makes the trap very versatile and some more work should be directed toward the investigation and development of this mount. (See Fig. 23)

A simpler method of mounting, that would however basically restrict the positioning of the trap to a horizontal support would be a nail or a spike fitting into the lower hollow rivet of the frame. Either steel spikes into wood supports or plastic spikes into the ground are recommended. Mr. Conibear provided for such a spike by drilling a hole in the lower pin at the fulcrum on the 220 NC. The

Fig. 28

Spring Tensioner

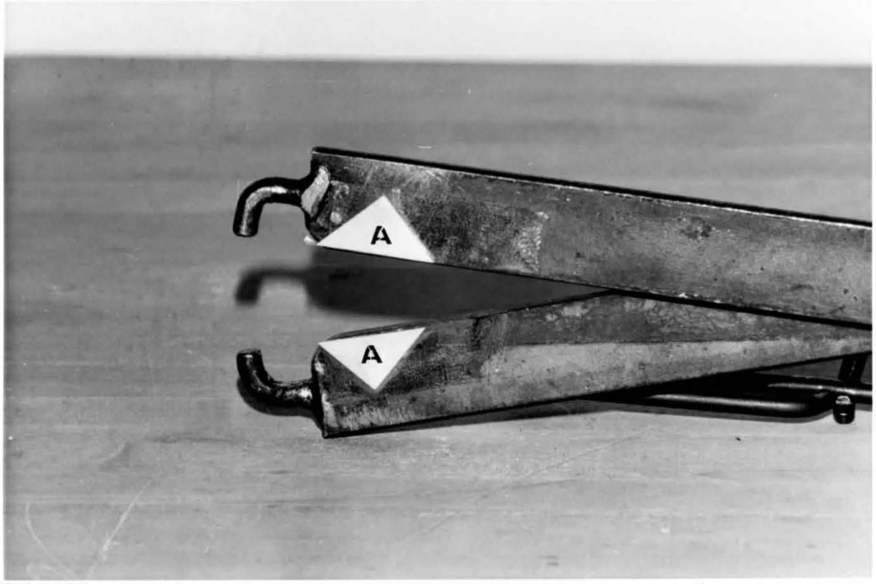

Fig. 29

Spring Tensioner - Suggested Hook modification (A). Hooks are incorporated into lever arms.

metal mounting intended for the 330 NC will be relatively costly in production and it is believed that a plastic mounting as described previously will be sufficient in supporting the 330 NC.

It was not possible to give enough consideration to the development of these mounts and it is recommended to continue the investigation in this area. The prime importance should be directed towards inexpensive production of these mounts.

I. Conclusion

The problem for this project, as far as the Conibear Series is concerned, was to examine, evaluate and optimize the traps designed by Mr. Conibear, who is presently one of the top humane trap designers.

In many instances a high degree of optimization had been achieved by Mr. Conibear, other aspects of the trap, however, needed revision and suggestions for improvement are outlined in the previous pages.

In summary an itemized optimization table has been prepared for a convenient, condensed reference to the Conibear-Optimization material. The table will be set up in five columns: the first column will refer to a particular item of a trap and identify the item to the appropriate trap; if items refer to all traps, no particular identification is given. The second column will show Mr. Conibear's reasoning behind a particular item of the trap. The third column discusses the degree of optimization reached by Mr. Conibear. The fourth column will provide suggestions for improvement and optimization. The final column will note whether additional work is required after the present project is completed. However, no detailed discussion will be given in any of the columns; this can be found in the previous pages.

The 110 NC and the 220 NC featuring the new frame demonstrate definite potentials, as they were outlined in detail above. Although these traps are only powered by one spring, the results from the energy evaluation show that such a configuration will effectively satisfy the present requirements after alterations on the design as recommended above have been carried out. Additional minor design changes on the traps become feasible as soon as further detailed information becomes available from the Guelph program.

The 330 NC with the essentially square shaped frame seems to be sufficiently effective for the present, as was claimed by Mr. Conibear. An increase in total trap energy to the temporary desired levels should be reached by redesigning the springs.

The Conibear Series in general has its great advantage in its spacial field of operation. Due to the fact that the Conibear trap reaches out in two directions the probability of hitting the animal is quite large (relative to a trap with a planar field of operation which will be discussed later).

Optimization Table - Conibear Traps

Trap Item	Mr. Conibear's Intent for Trap Item	Degree of Optimization Reached by Mr. Conibear	Suggestion for Optimization	Recommendation for Further Work
The Frame (Ref. to 110 NC & 220 NC)	-large visual upper area -increased clamping force -proportion of upper to lower part -lower narrow part for animal control	Optimized according to present information on animal statistics and behaviour	none at present	as soon as additional data is available
The Frame (Ref. to 330 NC)	-unchanged from previous 330	Optimized according to present information	none at present	none at present
Spring Stops (Ref. to 330 NC)	-prevent springs from slipping over corner	Serves intended purpose	pockets in frame as outlined on p. 69	none
Shape of Upper End Members (Ref. to 110 NC & 220 NC)	-increased clamping force	not optimized	reshaping of upper end members as outlined on p. 69	none

Optimization Table - Conibear Traps con't.

Trap Item	Mr. Conibear's Intent for Trap Item	Degree of Optimization Reached by Mr. Conibear	Suggestion for Optimization	Recommendation for Further Work
Joining of Trap Frame Halves	-method of production	not optimized	joining of frame halves as outlined on p. 69	none
Self Adjusting Jaw Features	-adjustment of jaws	not optimized	recommendation for deleting this item, see p. 74	none
Springs	-to gain maximum energy and maximum clamping force	not optimized	recommendation for new spring as outlined on pp. 83, 85	revision as soon as additional data becomes available
Spring Material	-no recommendations	not optimized	recommended material as outlined on p. 81	none
Spring Release Feature	-safety item	not optimized	recommendation for improvement see p. 88	further work required

Optimization Table - Conibear Traps con't.

Trap Item	Mr. Conibear's Intent for Trap Item	Degree of Optimization Reached by Mr. Conibear	Suggestion for Optimization	Recommendation for Further Work
Trigger Systems (Ref. to 110 NC & 220 NC)	-pan trigger suggested for reason outlined on p. 94	not optimized for reason given on p. 94	recommendation for additional pan type trigger, p. 96; also prong type trigger, p. 91	further work required
(Ref. to 330 NC)	-unchanged from previous 330 model	fulfils its intended function	none at present	none
Safety Lock	-to lock trap and springs during setting procedure	not optimized	recommendation for improvement, see p. 97	none
Spring Tensioner	-auxiliary tool to preload springs	not optimized	recommendation for improvement see p. 101	none
Trap Mounting	-to hold traps in desired positions	fulfils its intended function	no recommendations given	further work required

CHAPTER III - OPTIMIZATION - JACOB

A. Introduction

The New Jacob Trap was received to this project as a mechanism built by Mr. Jacobs after having developed a new concept in trap design. (See Fig. 30) The principle of this mechanism was subsequently utilized in designing a series of three traps which were similar in their configuration but differed in their respective sizes. (See Fig. 5) The three traps were intended for the animal groups I, II and III respectively as they are defined in APPENDIX D. As far as their application to the individual animal groups is concerned, the Jacob Traps are compared to the previous Conibear Series in the following way:

Previous Conibear	New Jacob Trap
110	JA I
220	JA II
330	JA III

In the discussion below the Jacob Traps will be referred to by this notation.

One of the trap's main features is its simplicity in configuration. It consists essentially of only three major parts, two of which make up the frame and the third being the trigger:

Frame - a strip of flat steel spring
- a pair of jaws

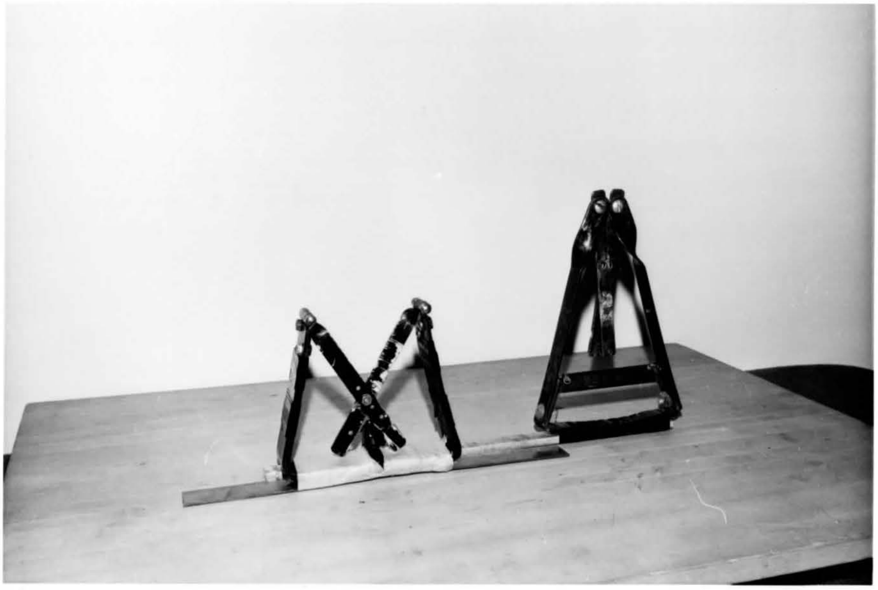

Fig. 30

New Jacob Trap - Concept

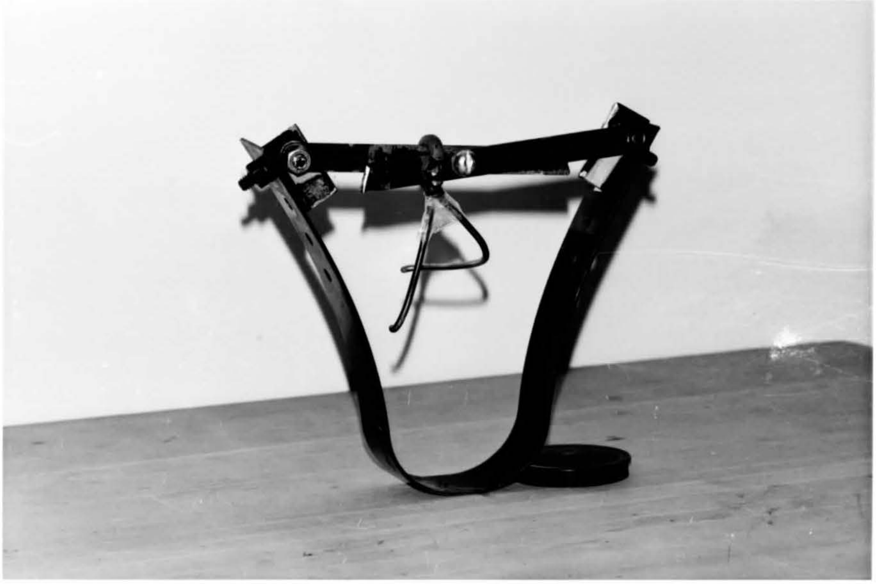

Fig. 31

New Jacob Trap (JA I) - Trap in Set Position

Trigger - prong trigger.

The trap, in the set or open position, has the form of an inverted isosceles trapezoid. (See Fig. 31) The trap's open position is secured by a c-clip prong trigger which restrains the movement of the jaws. Also, due to the configuration of the Jacob Trap, the total kinetic energy which is developed will be concentrated at one spot of the animal's body. Compare this to the Conibear trap, where it is possible that the trap will contact the animal in two spots and the total energy be divided accordingly. Of course, as mentioned previously, additional animal research should tell whether a certain amount of energy concentrated at one spot of an animal's body is substantially more effective as the same amount of energy divided into two simultaneous blows.

The design and qualitative optimization of the Jacob Trap was based also on the optimization criteria as outlined on page 54.

B. Validity of Proposed Trap

The proposed Jacob Trap has one distinct disadvantage which is its planar field of operation. This disadvantage is not unique with the Jacob Trap but exists with any other planar trap. The problem lies in the increased difficulty of animal control. A trap which operates in a three-dimensional space has a much greater chance to hit the animal along the longitudinal direction than has a planar trap which can contact the animal in only one spot, directly in its plane of motion.

For that reason the possibility of converting the Jacob Trap into a three dimensional trap was investigated. A configuration with a spring frame of several inches wide and two pair of jaws located a certain distance apart and mounted on this frame was investigated. Also two individual traps connected together, resulting in one unit was considered.

However, none of the investigation was successful due to the loss of simplicity of the mechanism, increased difficulty with the trigger system and increased cost of production.

It became apparent that the Jacob model lends itself primarily to the design of a planar trap. Also, the possibility of constructing the spring frame of several parts instead of one was considered. This would have taken the form of a straight base and each moment arm mounted individually on the sides of the base. Again, however, loss of simplicity and increase in cost would have been the result. Therefore it was concluded to adopt the proposed configuration as recommended by Mr. Jacobs.

C. The Frame

The Jacob Trap, as recommended by Mr. Jacobs, commends itself due to its simplicity in configuration.

In the optimization process the design of the frame was carried out in two stages. First, the frame was idealized as a five-bar kinematic chain with the spring made up of the base and two input links and the jaws forming the two output links. (See Fig. 32) A systematic investigation into several kinematic models was then followed through.

Upon obtaining a satisfactory kinematic chain, the second stage of the frame design commenced. Up to this point the above linkage was not proportioned to suit a particular animal size. The aim then was to scale this linkage for the three animal groups which are presently under consideration and design the spring as well as the jaws which together make up the frame.

D. The Frame as a Kinematic Chain

Recalling the importance of animal control, the animal's position in relation to the trap at the moment the trap is triggered, it becomes apparent that the prime factor in the design of the Jacob Trap is to obtain a ratio for total space within the set trap to the space swept by the jaws, of as close as possible to one. The larger the space which is swept by the jaws, the smaller the probability of missing the animal within the trap.

It also seemed important to center the animal in the trap's transverse direction. This would assure that the animal is located very near the center of the approaching jaws. The impact energy would then be lethaly absorbed by the animal in a single blow.

Furthermore, since it is important to obtain sufficient clamping force after the trap has closed on the animal, a high mechanical advantage in the jaws was aimed for.

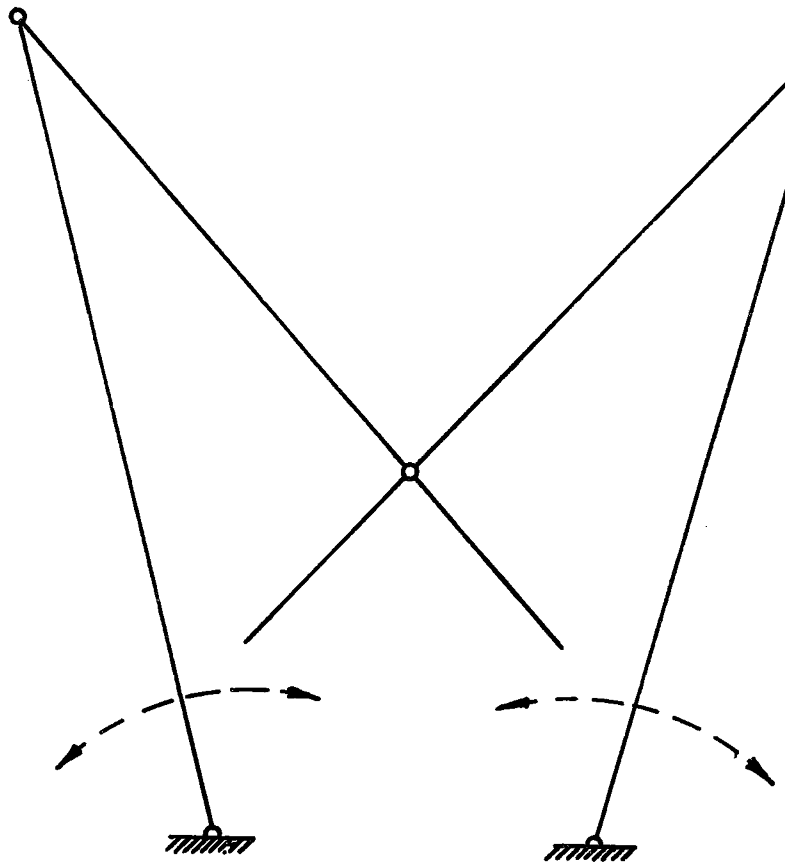

Fig. 32

Jacob Trap as a Kinematic Chain

Finally, the overall geometry of the trap had to be constrained to a reasonable size. As far as the geometry was concerned throughout the work on the Jacob Trap, the previous Conibear Series was used as a scale and a relationship was established between the two traps on an intuitive basis.

For the above reasons it was necessary to first find a mechanism which would substantially satisfy all previously mentioned criteria and a five-bar kinematic chain lent itself well to the purpose of analyzing such a mechanism.

In summary, the four criteria for the first design stage are:
- aim to center animal in trap's transverse direction
- maximize mechanical advantage of jaws
- maximizing space sweep of jaws within trap
- minimize overall geometric size of trap.

Keeping the above in mind, several kinematic models were built and investigated. At that point the models were not intended to suit a certain animal group but were developed only to satisfy the above four criteria.

A base with an arbitrary length was assumed (4.0 inches). This base was kept constant throughout the investigation and the moment arms were changed. Realizing that in the trap's closed position the jaws should also be completely closed, it is necessary for the moment arms of the trap to be closed at the top, forming an isosceles triangle. As a result, the total length of one jaw is restricted to the height of the trap in the closed position. The optimum ratio which was obtained and satisfied the previously outlined criteria was:

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

Such a configuration with a relatively narrow base forces the entering animal towards the center of the trap, directly below the center of the jaws. The space sweep of the jaws was satisfactory and enclosed almost the total lower half of the trap. This is important, since the animal will be located in the lower part. The mechanical advantage is approximately 2. The ratio of $\frac{2.25}{1}$ is not too large so that one can expect the overall geometry of the individually proportioned traps to lie within reasonable limits.

A ratio less than the proposed optimum demonstrates an unsatisfactory space sweep, less mechanical advantage and a wider base resulting in ineffective centering of the animal in the trap. A ratio larger than the proposed optimum yielded an unacceptable increase in overall size of the trap.

The kinematic model with the ratio $\frac{2.25}{1}$ had the following measurements:

base	4.0 inches
input links (left and right moment arms)	9.0 inches
output links (upper part of jaw)	5.5 inches
lower part of jaw	2.5 inches
total length of jaw	8.0 inches

In the completely open position, when both jaws coincide with the horizontal, the total inside height of the model was 8.25 inches.

In the second stage of the design, this model was now scaled to suit the three animal groups under present consideration. The traps of the previous Conibear Series are all square shaped and have the following dimension:

110	5.0 inches x 5.0 inches
220	7.0 inches x 7.0 inches
330	10.0 inches x 10.0 inches

From these figures it was decided to scale the Jacob Traps, when fully open, to a height 1.0 inches larger than the equivalent Conibear model.

Conibear (in set Position)		New Jacob (in set Position)	
model	height (in.)	model	height (in.)
110	5.0	JA I	6.0
220	7.0	JA II	8.0
330	10.0	JA III	11.0

The additional 1.0 inches in height on the Jacob Trap is to allow for the low energy to be expected in the first few degrees of motion of the trap.

Having determined the height of the Jacob Traps all other design variables were calculated accordingly and the following configurations resulted:

	JA I	JA II	JA III
base (in.)	2.9	3.8	5.3
moment arms (in.)	6.5	8.75	12.0
upper part of jaw (in.)	4.0	4.8	7.3
lower part of jaw (in.)	1.8	2.9	3.3
total length of jaw (in.)	5.8	7.7	10.6

these dimensions formed the basis for the design of the spring.

E. Spring Design

After some preliminary calculation it became apparent that it was not possible to design a spring according to the shape which had resulted from previous investigations, that is, the shape of an upright positioned isosceles triangle. Due to the relatively large deflection of the moment arms of the spring (deflection is approximately 50% - 60% of total length of moment arm), the stress at the point where the moment arm joins the base by far exceeded the allowable working stress, $S_{max.} = 195{,}000$ psi. In addition to the large deflection a substantial force was required at total deflection, such as approximately 40 pounds, 65 pounds and 90 pounds for the JA I, JA II and JA III respectively. This force was set arbitrarily, to some extent in accordance with the performance of the Conibear traps.

In order to stay below the maximum allowable stress and to obtain the required force, it was necessary to introduce a substantial radius in joining the moment arms to the base, keeping all other previously calculated dimensions constant. (See Fig. 33)

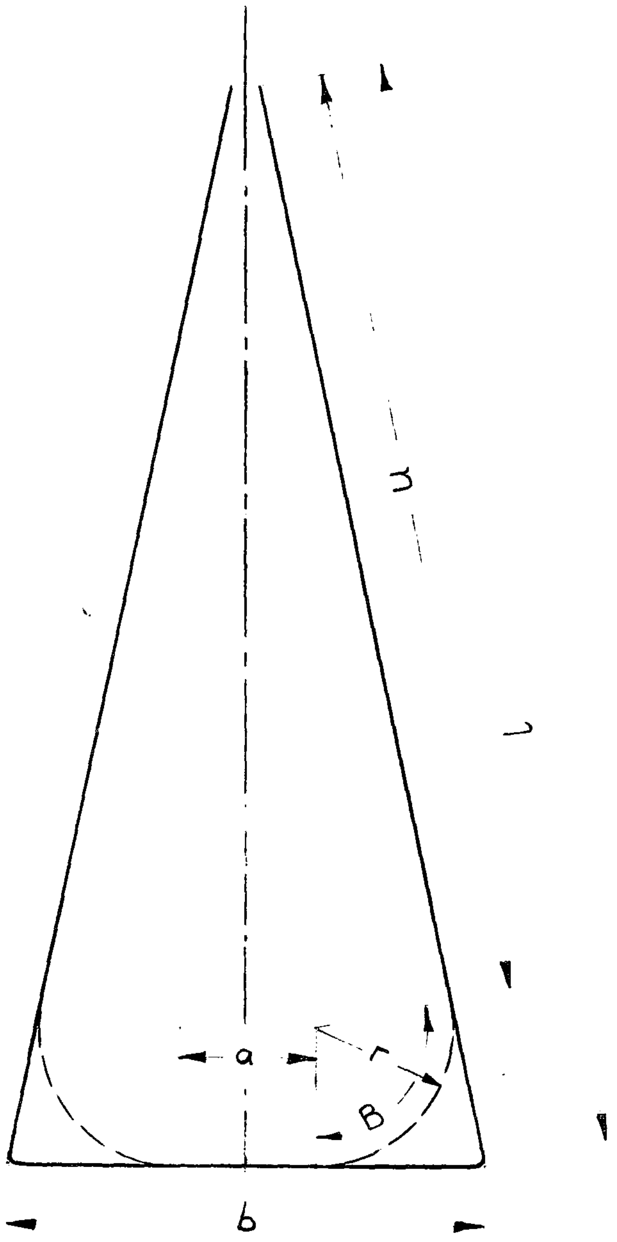

Fig. 33 schematic outline of spring

solid line - optimum kinematic model

broken line — radius necessary for spring design

Consequently, the design of the spring was carried out by applying the design equations for curved springs which are developed in REFERENCE (5). See APPENDIX E for Spring Design Equations.

F. Jacob Trap - Spring Design

JA I - From kinematic consideration the optimum configuration of the spring yielded a base b = 2.9 inches and a moment arm l = 6.5 inches. (See Fig. 33) A radius r = 1.0 inches was chosen which reduced the straight section of the base to a = 0.4 inches. The angle joining the moment arm to the base is B = 102 degrees = 1.78 radians. The correction factor k = 0.96 is the same for all Jacob Traps under consideration. The length of the straight section of the free end of the spring u, was calculated by geometric consideration and expressed as a function of the length of the moment arm l, the radius of curvature r and the angle of curvature B expressed in degrees, $u = l - r / (\tan (180 - B)/2)$.

Also from the kinematic model the deflection T for each moment arm of the JA I was found to be T = 3.5 inches.

Utilizing both the deflection and stress equation for the spring under consideration and solving for h, the required thickness of the material was determined, h = 0.0678 inches.

It was now necessary to find the width of the material which would assure the required force F of approximately 40 pounds at full deflection.

A width of b = 1.5 inches seemed the maximum allowable value. The spring with b = 1.5 inches would yield a force F = 36 lb. at full deflection and a spring constant C = 5.15 lb/in .

JA II and JA III - The springs for the JA II and JA III have been analyzed and designed in exactly the same manner as the spring for the JA I. For that reason only the design parameters for these traps will be listed.

In summary, the design parameters of the JA I, JA II and JA III are as follows:

	JA I	JA II	JA III
b - width of spring material (in.)	1.5	1.75	2.0
h - thickness of spring material (in.)	0.0678	0.10	0.125
a - straight part of base (in.)	0.4	0.9	1.0
r - radius of curvature (in.)	1.0	1.2	1.75
B - angle of curvature (degrees)	102	102	102
u - length of straight section of free end of spring (in.)	5.8	7.75	10.3
F - force obtained at full deflection (lb.)	36	67	88.3
C - spring constant (lb/in)	5.15	8.02	6.8

The parameter u takes into consideration the mounting of the jaws by means of an angle piece fastened to both the spring as well as the jaws. This angle piece is positioned along the center of the width of the material, and 0.5 inches from the free end of the straight section of the moment arm.

G. Spring Material

The material to be used for the spring of the JA Traps is the chromium alloy AISI 5160. For detailed discussion see Springs page 78.

H. The Jaws

The spring of the Jacob Trap in conjunction with a pair of jaws make up the frame of the trap.

The lengths of the jaws were determined at the time of optimization of the kinematic model which has been described previously.

For purposes of trap evaluation, the jaws were made out of flat steel 0.125 inches x 0.5 inches. The longitudinal dimensions are as follows:

	Total length (in.)	Distance from mounting to point of rotation of jaws (center to center - in.)
JA I	5.0	3.0
JA II	6.3	3.7
JA III	9.4	6.0

With these dimensions the lower end of the jaws in the trap's closed position come within a certain distance from the bottom of the trap. These distances are 1.2 inches, 2.2 inches and 2.3 inches for the JA I, JA II and the JA III respectively. It is therefore recommended that an anvil plate be installed at the bottom of the trap which is positioned upright in the transverse direction, (See Fig. 34) with a height equal

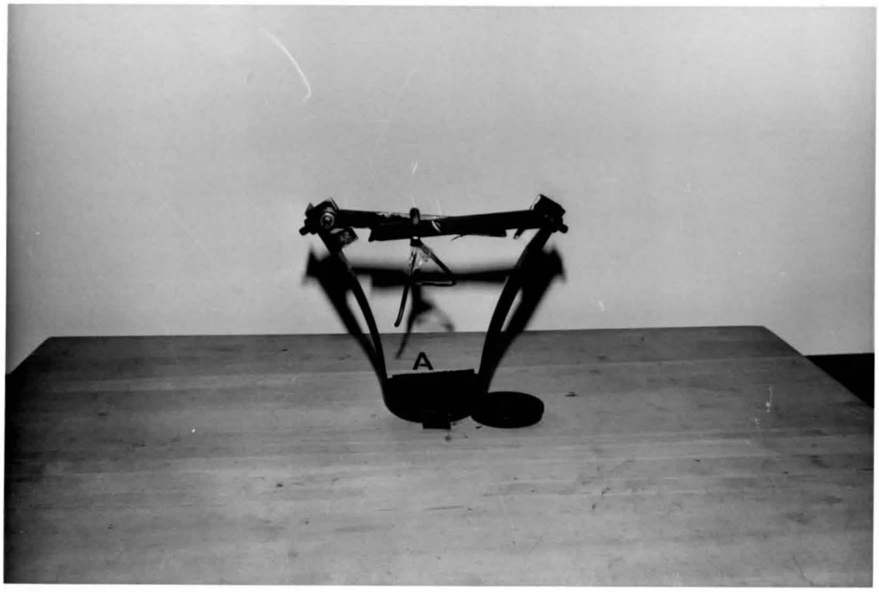

Fig. 34

Anvil Plate in Trap's Set Position

A- Anvil Plate

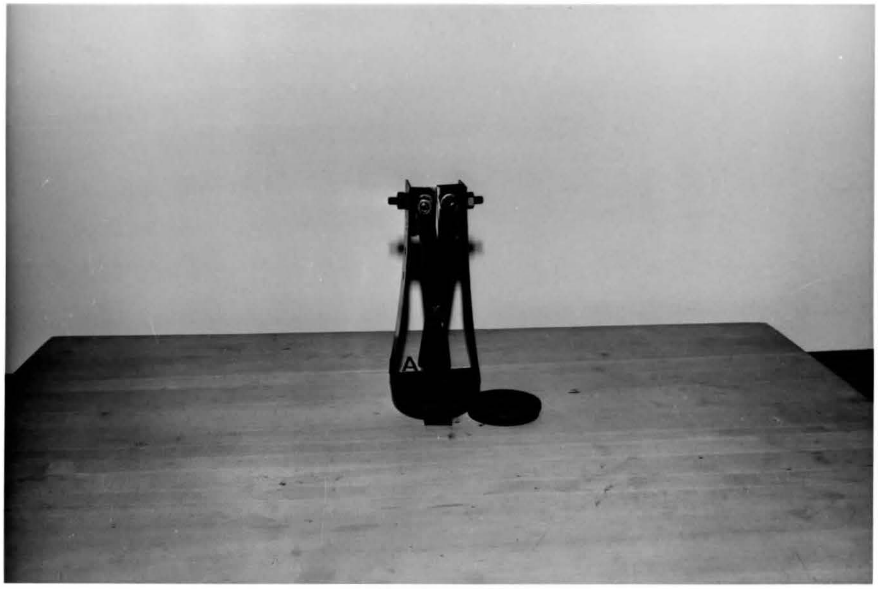

Fig. 35

Anvil Plate in Trap's Closed Position - A - Anvil Plate to the distance from the bottom of the trap to the lower points of the jaws in the traps closed position. (See Fig. 35)

After the trap is triggered, the animal will be squeezed between the jaws and forced against this plate. In earlier work it was thought to catch and clamp the animal only between the lower parts of the jaws, however, it is now believed that a considerable advantage can be gained by utilizing the vertical force component as well as the horizontal one. With a plate positioned below the animal's throat the probability of restricting the air passage to the animal's lungs is much higher than with only a horizontal clamping force applied by the jaws from both sides.

Since, during the motion of the trap, the frame constantly deforms, it is not possible to rigidly mount the lower plate in a variety of locations. The only possible place would be the straight center part of the spring's base. In the transverse direction the lower plate would take on the form of the inside shape of the closed trap from the bottom to a height of 1.2 inches, 2.2 inches and 2.3 inches for the JA I, JA II and JA III respectively.

As a safety feature for the trap's set position, it is recommended that one of the jaws be equipped with a rigidly attached stop which would allow the jaws to just pass the point of maximum deflection of the moment arms in the upward direction, but would restrain it from any further movement. This would allow the trapper to handle and place the trap in the open, or totally deflected position and afterward, with only a minute amount of effort, set the trigger. This would be especially convenient for places where it is not possible to tension the trap after it has been set. Furthermore, it is important to round off all sharp edges on the jaws which can contact the animal, to insure that the pelt is not cut or otherwise damaged.

I. Trigger Systems

The importance of an effective trigger must be re-emphasized again. A trap will not be accepted if it has an unreliable, unsafe or difficult to operate trigger mechanism. A detailed discussion on trigger systems was presented before and will not be repeated here.

For the Jacob Trap both types of trigger systems, the prong trigger as well as the pan type trigger have been investigated.

Pan type Trigger - It is believed that the pan trigger does not lend itself well to a planar trap for the following reason:

- due to the fact that the trap operates in a planar field, the animal must be well positioned in relation to the trap at the moment of firing, to assure a humane kill. This, it seems, cannot easily be achieved with a pan trigger.

To assure that the animal's paw and consequently its head or neck is close to or in the field through which the jaws sweep, the pan must be quite narrow. If the pan is too narrow however, the animal may easily step over it.and through the trap without setting it off.

On the other hand, if the pan is wide enough to force the animal on it when passing through the trap, the animal may step on the pan and trigger the trap before it is even close to the jaws.

The investigations into a solution to a simple, reliable and safe pan trigger were not very successful. This was due to:

- consideration given to the prime optimization criterion, Animal Control, as was outlined in the previous paragraph,
- difficulty in mounting and controlling a pan trigger because of the constant change in shape of the frame during its motion as well as the anvil plate which is mounted on the bottom of the trap.

For these reasons a pan trigger does not seem practical for the Jacob Trap.

<u>Prong or Prop Trigger</u> - Several prong triggers have been investigated in conjunction with the Jacob trap. The prop trigger which was recommended by Mr. Jacobs was not too effective for several reasons.

The prop in its present configuration needs a relatively large force in order to move it away from under the jaws and set off the trap. Even if it could push the prop ahead, the animal would have little chance of getting into the trap. The probability of missing the animal is quite high.

Also, the wire of the prop can easily be bent. This is especially crucial since a small decrease of the prop in height means a lower position of the center of the jaws. However, this results in a substantial increase in force of the jaws unto the prop which would increase the amount of force necessary to trigger the trap even more.

Finally, the prop mounted in the lower part of the trap may promote freezing of the trigger. Mr. Jacobs intended this prop trigger to be manufactured in several sizes to suit the various animal species under consideration.

A trigger that is believed to be more effective and is recommended for the Jacob Traps consists of a circular ring which is cut open to form a "c". (See Fig. 36)

This c-clip is positioned over both jaws in the traps open position restraining their movement. (See Fig. 37) The jaws are free to move however, upon a slight rotation of the c-clip. This rotation is initiated by two prongs fastened to the c-clip in the vertical down direction. As soon as the animal pushes on the prongs, it will turn the c-clip and the jaws will be released. At the place where the c-clip is positioned over the jaws, the jaws will have to have a small groove at the points of contact with the c, in order to accomodate it. This would also prevent the trigger from slipping sideways.

The advantage of the c-clip is two fold:

- first the opening can be varied to obtain more or less rotation in the c before the jaws are released. This means that different c-clips can be made for different animals, depending on the longitudinal distance required for a certain species to be well located in the trap before firing.
- secondly, the c can be made longer in the vertical direction. This

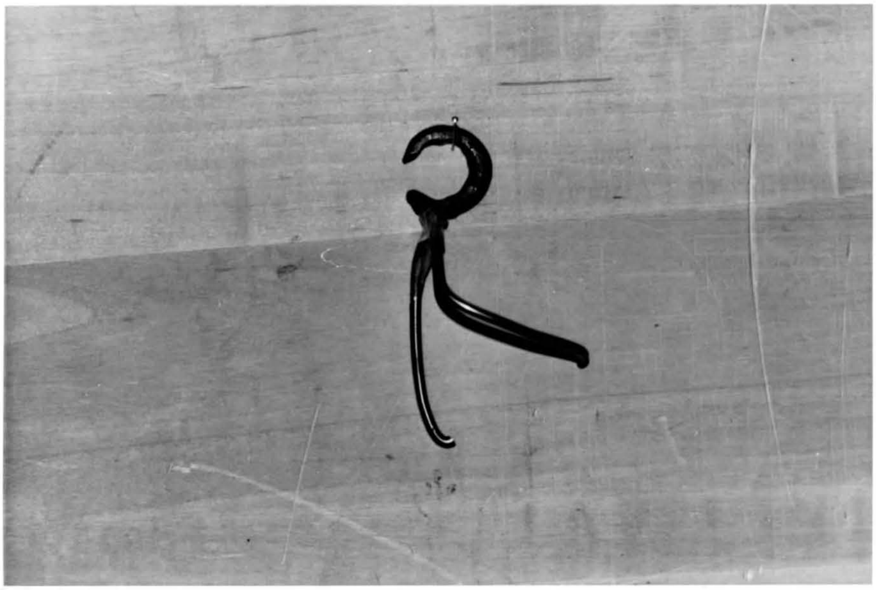

Fig. 36

C - clip - recommended prong type trigger for Jacob Trap

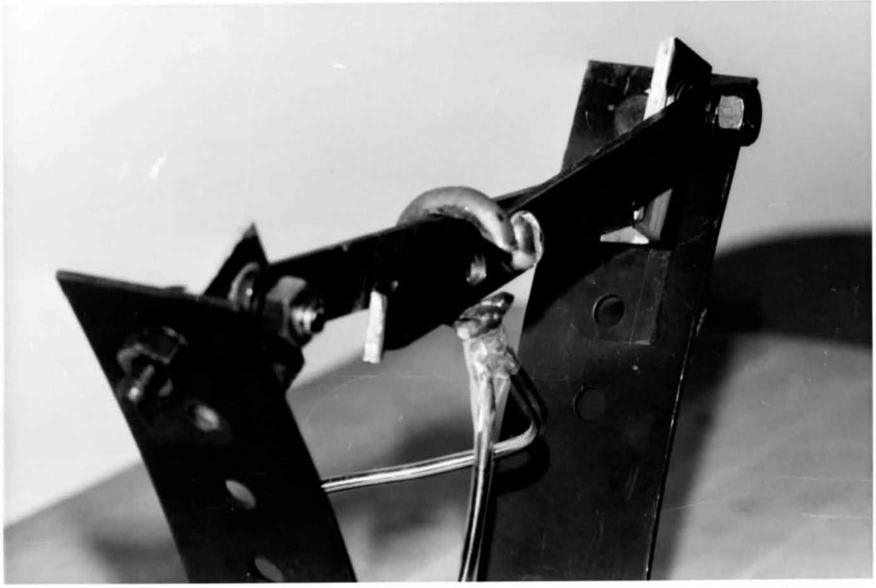

Fig. 37

C - clip mounted on jaws in Trap's Set Position will result in a greater force being exerted by the jaws unto the c-clip, which in turn will require more force to be exerted by the animal in order to activate the trigger. In this manner it is possible to obtain sensitive as well as hard trigger sets. This would allow a trapper to pre-select, to some extent, a certain trigger for a certain animal. If, for instance, the trap is to be set for a large, strong animal he would select a trigger which could normally not be moved by a smaller, weaker animal. This would prevent killing animals which a trapper does not wish to catch. The length of the prong wire can also be varied, which would result in the trigger being activated only by animals of a desired height. The correct sizes and shapes of the c-clips for individual animals as well as the exact length of the prongs can only be determined at a later date.

J. Energy Evaluation of Jacob Trap

Due to the relatively complicated kinematic configuration of the Jacob Trap frame and its constant change of shape, during the trap's motion it was not possible to apply any of N. Johnston's evaluation routines directly. Again, a kinematic model helped in simplifying the analysis. The following assumptions were made:

- mechanism (trap) is completely symmetric
- the input crank (moment arm of trap) does not change in length appreciably during motion of mechanism, and
- center point of rotation of jaws moves in a vertical direction.

These assumptions were experimentally justified. The right half of the trap was idealized as a slider crank mechanism. (See Fig. 38) The

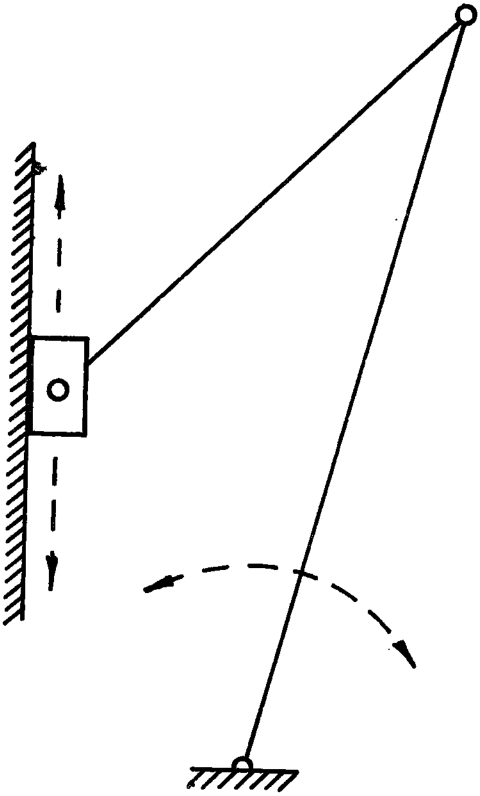

Fig. 38

Half of Jacob Trap as a Slider Crank Mechanism slider crank mechanism had the following configuration:

Base - an imaginary point of rotation of the input crank (moment arm of trap), located at the base of the trap.

Input crank - moment arm of the trap

Coupler - upper part of right jaw

Slider - imaginary, slider located at the center point of rotation of jaws.

It was now necessary to observe the motion of the input crank (moment arm of trap) as well as the motion of the coupler (upper part of jaw). A program was developed which consisted of N. Johnston's program for evaluating a trap with a single rotating jaw, a program developed by M. Sutherland (6), which calculates the angular velocity of a coupler on a slider crank mechanism and additional modifications necessary in obtaining the final total energy.

Due to the extended program, additional input data becomes necessary.

List of Input Data:

A - width of jaw material

B - thickness of jaw material

NAME - trap name

LENGTH - equal to 1.0 (not defined in this program)

ANGTOT - total angle of sweep of moment arm

NUMBER - number of exposures considered

X(1) - total length of moment arm

X(2) - length of upper part of scissor

Input Data con't.

X(3) - excentricity of center of jaws (slider) to base

STRTA - starting angle of moment arm in trap's open position, measured counter clock wise, from a vertical passing through the imaginary basepoint (See Fig. 38)

C - total length of one jaw

ERTIA - inertia of right moment arm of trap

FRAME - number of frames per interval

BL - length of upper part of scissor = X(2)

MORE - repeat card (number 4 repeats process for new trap)

List of Input Data which has to be determined from film, (direct measurements from film should be considered).

UL - length of upper part of scissor

OP - vertical distance between center of jaws and bottom of trap

D - radius of rotation for coupler

ANG - cumulative angle of moment arm

OP, D and ANG - have to be measured at each position during the motion of the film.

The output of the program yields the total energy of the trap at various intervals and the format of the printout was kept identical to N. Johnston's output format.

OPEN is the distance between the center of the jaws and the bottom of the trap.

K. Trap Mounting

The Jacob Trap in its present configuration does not stand well by itself and an additional mounting which will hold the trap in its set position will be necessary. No detailed investigation into a particular mounting has been carried out in this project and additional work is needed. It is recommended that the possibility of combining the support for the lower plate, which has been outlined previously, with a mounting plate for the trap be investigated. However, consideration must be given to the fact that the trap's shape is constantly changing during its motion.

L. Spring Tensioner

Again, this is a feature which needs additional attention. Due to the strong spring, the Jacob Traps are difficult to tension manually and it is also a dangerous task. Two levers, each approximately 12.0 inches to 18.0 inches long, which fit tightly over the free ends of the frame arms would produce sufficient mechanical advantage and permit a trapper to pry apart a trap in order to set it.

M. Conclusion

Mr. Jacobs, also a top humane trap designer, had developed a unique mechanism by applying a basic mechanical principle to the design of a humane trap. At present the configuration of this trap is unique among existing traps. The problem for this project differed from the work on the Conibear Series as was outlined on page 65. Again an itemized optimization table has been prepared for a conveniently condensed reference to the Jacob Optimization material.

The table will be set up in four columns similar to the previous summarizing table on the Conibear Series. The first column will refer to a particular item of the trap, but will in all cases refer to all three traps. The second column will show Mr. Jacobs' reasoning behind a particular item or aspect of the trap. The third column discusses the degree of optimization established within the present project. The last column will note whether additional work is needed after the present project is completed.

Again, no detailed discussion will be given in any of the columns; this can be found in the previous pages.

The Jacob Traps performed relatively well as far as the energy values above water are concerned. (See Specifications on Jacob Trap) However, below water the energy loss is substantial. This is due to the drag developed by the large surface area of the moment arms, normal to the direction of motion of the trap.

The energy loss is the greatest with the JA III, since this trap has the widest spring frame and consequently produces the largest surface area. The clamping force compares well to other traps. As mentioned previously, the simplicity in configuration commends this trap. Its overall physical geometry lends itself well for storing or packing. Besides the substantial energy loss under water, a second disadvantage which has been pointed out previously, is the trap's planar field of action, and the difficulty of animal control with such a trap. However, it is believed that this weak point may be overcome to a large extent by the use of several appropriate c-clip triggers for various animals as has been outlined previously, and that additional field research will justify that prediction.

Optimization Table - Jacob Trap

Trap Item	Mr. Jacob's Intent for Trap Item	Degree of Optimization established with presently available facts on animal research	Recommendations for Further Work
Validity of proposed trap	-simplicity in design -mechanical advantage due to jaw configuration yield high clamping force	not applicable, since these are internal design features	none
Frame (Spring & Jaws)	-simplicity of frame	feature of design	none
	-geometric proportion, suiting various animal species	optimized according to present information, see p. 118	revision as soon as additional data becomes available
Frame	-centering animal for animal control	optimized, see p. 116	none
	-space sweep of jaws	optimized, see p. 116	none
	-maximum mechanical advantage	optimized, see p. 116	none
	-overall size of trap	optimized, see p. 116	none
Spring	-maximum impact energy	optimized, see p. 120	none
	-maximum clamping force	optimized, see p. 120	none
Spring Material	-no recommendations	recommended material, see p. 81	none

Optimization Table - Jacob Trap con't.

Trap Item	Mr. Jacob's Intent for Trap Item	Degree of Optimization established with presently available facts on animal research	Recommendations for Further Work
Jaws (length)	-for optimized frame configuration	optimized, see p. 122	none
Jaws, total configuration	-for optimized jaw configuration	not optimized	additional work required
Anvil Plate	-to squeeze animal against plate after impact	partially optimized, see p. 124	additional work required on mounting of anvil plate
Trigger System	-sensitive trigger with relatively high animal control	partially optimized, see p. 126	additional work required regarding c-triggers for various species
Trap Mountings	-to hold trap in position	not optimized	additional work required
Production Model of Jacob Trap	-for most economical manufacturing	not optimized	additional work required

CHAPTER IV - RECOMMENDATIONS FOR FURTHER WORK

A. Introduction

The results of the investigation of this project clearly indicate the necessity for a continuation of the Humane Trap Development Program. Future work in Mechanical Engineering should concentrate on:

1. in depth study of several areas of trap design
2. testing and evaluation of modifications of trap features as recommended in this project
3. additional investigation into trap features which did not receive sufficient attention during the present project.

As far as a future program is concerned, it should be carried out in close relation to the research work undertaken at Guelph University. The importance of this point has been demonstrated throughout this report.

B. Mechanical Engineering

Points 2 and 3 above are self explanatory, they have been discussed in detail throughout CHAPTER II and need not be repeated. However, as a result of detailed investigation, it is believed that several areas of trap design are of major importance and should receive special attention.

The main problem which is found with all presently existing traps is the substantial energy loss below water. This loss varies from one trap to the next depending on the surface area of the moving parts which are normal to the direction of motion of the trap. The problem is serious, since most traps are used extensively below water.

It is seen from the test results, that no trap loses less than 50% of its energy below water, in fact, the energy loss of many traps is substantially higher. Therefore any trap whose performance is optimized above water will be ineffective below water. On the other hand, if a trap were optimized to satisfy requirements below water it would be over designed for above water operation. For this reason it is believed that a certain trap cannot be optimized for both above and below water operation at the same time. A possible solution to the problem would be a trap which would be equipped with two springs (or two sets of springs) one stronger than the other, which are optimized to deliver the required energies above and below water respectively. The Conibear-type spring with its spring release feature would lend itself well to this purpose. The frame of the trap could remain unchanged.

The trigger system on any trap is of great importance, as has been pointed out previously. Although a variety of triggers for all traps under present consideration have been investigated and several have been recommended, additional study in this area seems justified. This is especially true as far as the pan type trigger is concerned.

Finally, some time should be spent on the study of possibilities for new concepts in trapping. The present trap in the form of a spring powered mechanism has been questioned. Is this present system practical?

As far as the difficulty of animal control is concerned, will it ever be possible to predict to a high probability a humane kill with the presently accepted spring powered trap. It is believed that these questions should be asked and the area of new concepts in trapping should receive some attention.

C. Zoology

Throughout the report the importance of additional results from the Guelph research program has been demonstrated. Detailed measurements and statistics of animal body sizes as well as cross sectional body shapes along the animal's longitudinal direction are needed in a final design of the geometry of the trap frames. Measurements of the animal's step length as well as a relationship between the animal's paw and its head or neck are important in trigger design.

Stuffed animals at the disposal of a trap designer would of course be ideal since the designer could then establish a direct relationship between the animal and trap under consideration.

A further area of study from which results are needed is animal behaviour with respect to various parts of the trap. The results of animal behaviour toward both the treadle as well as the prong trigger would clarify all pros and cons that exist with the use of these triggers. It would also be advantageous to verify the generally accepted opinion that a trapezoidal shaped trap is more inviting to an animal than a square shaped trap with the same amount of square inches of trap opening.

Finally, for a continued quantitative analysis, it is important to know the energies necessary to kill a certain animal and verify or change the presently established energies which were set at the previous Conibear Series plus 50%. It would also help to know the required static force (clamping force) which the trap must exert after it has closed on the animal, in order to prevent this animal, which might only be unconscious, to regain consciousness and suffer in the trap. Also, the possibility of a trade off between kinetic energy and static force should be investigated. In trap design it is possible to some extent to compromise between kinetic energy and static force, a good example of which is the series Northern Killer - New Instant Killer. Taking this into consideration it is quite likely that a certain combination of kinetic energy vs. static force offers a higher probability for a humane kill than any other combination.

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PART III

APPENDICES

APPENDIX A

PROPOSAL TO HUMANE TRAP DEVELOPMENT COMMITTEE

SUMMARY

The Department of Mechanical Engineering of McMaster University proposes to undertake the second phase of the humane trap evaluation and development program in 1971.

The work will be undertaken in two main parts with emphasis on the second of these:

1. A continuation of the trap evaluation program carried out in Phase 1.
2. Optimization of the design of two of the most promising traps.

The project is to be completed by 1 January 1972, and the total expenditure will not exceed $6,000.00. This will be carried out as a graduate student research project in the Master of Mechanical Engineering design program.

Liason will be maintained with the research program that is expected to be in progress at Guelph.

INTRODUCTION

The aim of Phase 1 was to establish standards by which humane traps may be judged because no systematic evaluation means had ever been undertaken. The work was carried out by Mr. Norman Johnston, and was reported in his Masters Thesis "Humane Trap Evaluation", McMaster University, November 1970. Joint supervision was provided by Dr. G. Kardos and Prof. W. R. Newcombe. Some preliminary investigations were made in this area by Mr. Zoli Beke and Mr. Peter D. Lawson and these are recorded in internal reports of the Department of Mechanical Engineering.

This project will be a continuation and logical extension of Johnston's work with the main emphasis on humane trap design optimization. We feel that further evaluation is necessary because several new traps have been developed which were not evaluated by Johnston, and the evaluation phase gives the designer a better appreciation of the factors and features that need to be considered in the optimization process.

DESCRIPTION OF PROPOSED WORK

The work will be undertaken in the two related parts listed below with the main emphasis placed on the second part:

1. A continuation of the trap evaluation program carried out in Phase 1.
2. Optimization of the design of two of the most promising traps.

1. Trap Evaluation - Four additional trap types that were not included in Johnston's work will be investigated to provide a more comprehensive evaluation of the humane qualities of existing traps. Also, as stated in the introduction, an important aim of this part is to give the designer an appreciation of what factors are important in trap design. The following traps will be evaluated:

(i) The New Instant Killer
(ii) The Canada Trap
(iii) The New Conibear Series
(iv) The New Jacob Trap

(v) Up to three additional traps.

The established Beke-Johnston evaluation technique will be used.

2. Trap Optimization

The design of two of the most promising traps will be optimized. The specifications to be satisfied are as follows:

- A humane trap must deliver the optimum blow in the optimum manner to kill the types of fur-bearing animals for which it is designed instantly and reliably. The trap must kill with a crushing blow without damaging the pelt, must hold the animal securely, and above all must minimize suffering.

As well as striving to obtain the most humane trap due consideration will be given to minimizing cost, bulk, weight and to maximizing safety, durability and reliability.

Based on the evaluations carried out to date the traps that appear to have the most potential are:

(i) The New Conibear Series

(ii) The New Jacob Trap.

Two series of traps such as these will be selected after the extended evaluation program has been completed, and their design will be refined and optimized. The overall aim of this program will be to improve the general performance as well as the following specific characteristics:

1. Energy - mass ratio

2. Application and amount of impact
3. Speed and clamping force
4. Animal control
5. Cost of production
6. Triggering methods
7. Setting and safety.

The minimum standard for an optimum will be considered to be the Conibear Series as updated by Guelph, and an interim energy target will be the energy of the Conibear Series plus 50 percent.

Liason with Guelph

A related research program is expected to be carried out for the Humane Trap Development Committee at the University of Guelph, and one of the aims will be to determine the optimum magnitude and delivery of the blow required from the trap. Calibrated testing traps will be required, and McMaster University will calibrate one large and one small Mohawk trap for this program. Also, we will maintain liason with Guelph, but this should not involve more than one-half day per week because of the shortage of time for the project.

FACILITIES

Equipment and facilities required for the program are presently available. This includes a high speed camera, glass sided flume for underwater evaluation, large research computer (CDC 6400) and a fully equipped machine shop. Sufficient laboratory space exists in the

Engineering Building of McMaster University.

Traps for evaluation or calibration are to be supplied by the Humane Trap Development Committee.

SCHEDULE - 1971

May 1 - Program starts with review of previous work.
Procure evaluation equipment.
Assemble equipment and set up evaluation area.
Calibrate Mohawk traps.
June 1 - Carry out evaluation program.
June 15 - Commence optimization program.
October 1 - Begin final report and continue optimization program.

BUDGET

Salaries - One graduate student May - December inclusive, 8 months at $300.00/month	-	$2,400.00
Computing time 3 hours at $500.00/hour	-	1,500.00
Supplies	-	500.00
Equipment and shop charges for trap calibration modifications	-	550.00
Travel	-	450.00
Publication costs	-	190.00
Miscellaneous	-	110.00
		$5,600.00

It is assumed that any traps used in this project will be supplied by the Humane Trap Development Committee. No funds have been included in the budget for the manufacture of prototypes or for making any major design changes in traps. However, funds have been included for the conversion of one large and one small Mohawk to calibrated traps to be used as standards in the Guelph program.

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 researcher will prepare a comprehensive thesis on the work done. This thesis, or abstract from it, will constitute the final report.

APPENDIX B

COMPUTER PROGRAM LISTING FOR JACOB TRAP

```
PROGRAM TO FIND THE KINETIC ENERGY OF THE JACOB TRAP

VARIABLE NAMES
                 NAME - TRAP NAME
                 ERTIA - INERTIA OF RIGHT MOMENT ARM OF TRAP
                 ANG - CUMULATIVE ANGLE TRAVERESED
                 TIME - TIME INCREMENT BETWEEN PHOTOGRAPHS
                 NUMBER - NUMBER OF EXPOSURES CONSIDERED
                 DT - TIME INCREMENT BETWEEN SUCCESSIVE EXPOSURES
                 TTOTAL - TOTAL TIME IN SECONDS FOR GIVEN MOTION
                 DANG - ANGLE INCREMENT BETWEEN SUCCESSIVE EXPOSURES
                 VEL - INSTANTANEOUS ANGULAR VELOCITY
                 EN - -INSTANTANEOUS KINETIC ENERGY
                 MORE - REPEATES PROCESS FOR SECOND TRAP
                 INTVAL - TIME IN SECONDS BETWEEN PULSES ON FILM
                 RATE - NUMBER OF FRAMES IN TEN MILLISECONDS
                 FRAME - NUMBER OF FRAMES PER INTERVAL
                 ANGTOT - TOTAL ANGLE OF SWEEP
                 OPEN - VERTICAL DISTANCE BETWEEN CENTER OF JAWS
                        AND BOTTOM OF TRAP
SUBROUTINE LIST
                 PLOTPT - STORES ORDINATE AND ABCISSA FOR PLOT
                 SCALE - LIMITS PLOT BOUNDS TO PRESENT RANGE OF VALUE
                 OUTPLT - DUMPS AND DESTROYS ALL STORED POINTS

FOR ANY ADDITIONAL INFORMATION SEE ' ENERGY EVALUATION OF JACOB TRAP

   REAL LENGTH
   REAL INTVAL
   DIMENSION NAME(7),ANG(99),TIME(99),VEL(99),DT(99),DANG(99),EN(99)
  1FRAME(99),OPEN(99),PHI(99),OP(99),DD(99)
   DIMENSION X(3),W1(99),T1(99),T1D(99),T2(99),W2(99),D(99),ENGY(99)

SECTION TO READ AND STORE REQUIRED DATA
   ICASE = -1
   ROH = 0.28
   A = 0.5
   B = 0.125
```

```
      INTVAL = .01
    4 READ (5,100) (NAME(I),I = 1,6)
      READ (5,102) LENGTH,ANGTOT
      READ (5,101) NUMBER
      READ (5,150) X(1),X(2),X(3),STRTA,C
      READ (5,151) (D(I),I=1,NUMBER)
      READ (5,152) (OP(I),I=1,NUMBER)
      READ (5,153) UL,BL
      DO 1 I = 1,NUMBER
      READ (5,102)FRAME(I),ANG(I)
      TIME(I) = INTVAL/FRAME(I)
    1 CONTINUE
      READ (5,103)ERTIA
C
C  SECTION TO CALCULATE THE REQUIRED QUANTITIES
      NUMB = NUMBER - 1
      DO 2 I = 1,NUMB
      VEL(I) = ((ANG(I+1)-ANG(I))*(3.14159/180.0))/((TIME(I+1)+TIME(I))
     12.0)
      EN(I) = (0.5*ERTIA*(1.0/32.2)*(1.0/12.0))*VEL(I)**2
      W1(I) = VEL(I)
      WRITE (6,502) VEL(I),EN(I)
  502 FORMAT (//,5X,F10.2,5X,F10.2)
    2 CONTINUF
      WRITE (6,504)
  504 FORMAT (1H1)
      X2SQ=X(2)*X(2)
      DO 10 I=1,NUMB
      ADD = 0.0174533*(ANG(I+1)-ANG(I))
      T1(1)=.0174533*STRTA
      IF(I.EQ.1) GOTO 3
C CALCULATING CRANK ANGLE IN RADIANS
      T1(I)=T1(I-1)+ADD
    3 X1S=X(1)*SIN(T1(I))
      X1C=X(1)*COS(T1(I))
      S1=X(3)-X1S
```

```
      S2=FLOAT(ICASE)*SQRT(X2SQ-S1*S1)
C CALCULATING COUPLER ANGLE
      T2(I)=ATAN2(S1,S2)
      X2S=X(2)*SIN(T2(I))
      X2C=X(2)*COS(T2(I))
C CALCULATING COUPLER ANGULAR VELOCITY
      W2(I)=-W1(I)*X1C/X2C
C CALCULATING INERTIA OF JAW
      DD(I)= D(I)*BL/UL
      XM = A*B*C*ROH
      XI1 = (A**2+C**2)*XM/12.0
      XI2 = XM*DD(I)**2
      XIT = XI1+XI2
C CALCULATING ENERGY OF JAW
      ENGY(I) = 0.5*XIT*(1.0/32.0)*(1.0/12.0)*ABS(W2(I))**2
      WRITE (6,503) W2(I),XIT,ENGY(I)
 503  FORMAT (//,5X,F10.2,5X,F10.2,5X,F10.2)
C.CALCULATING TOTAL ENERGY OF TRAP
      EN(I)=(EN(I)+ENGY(I))*2.0
      CALL PLOTPT (ANG(I),EN(I),4)
  10  CONTINUE
C
C  SECTION TO CALCULATE THE INCREMENTAL JAW OPENING
      DO 11 I=1,NUMBER
      OPEN(I) = OP(I)*BL/UL
  11  CONTINUE
C
C  SECTION TO WRITE THE RESULTS
      WRITE (6,110)
      WRITE (6,104)
      WRITE (6,105) (NAME(I),I=1,6)
      WRITE (6,106)
      WRITE (6,107)
      TTOTAL = 0.0
      YMAX = EN(1)
      DO 8 I = 1,NUMBER
```

```
      WRITE (6,108)FRAME(I),ANG(I),OPEN(I)
      IF (I.EQ.NUMBER) GO TO 8
      IF (EN(I).GT.YMAX) YMAX = EN(I)
      DT(I) =(TIME (I+1) + TIME(I))/2.0
      DANG(I) = ANG(I+1) - ANG(I)
      TTOTAL = TTOTAL + DT(I)
      WRITE (6,109)TTOTAL,DANG(I),VEL(I),EN(I)
    8 CONTINUE
      WRITE (6,104)
      WRITE (6,111)TTOTAL,ANG(NUMBER)
      YMAX = YMAX + 3.00000
      CALL SCALE (0.0,ANG(NUMBER),0.0,YMAX)
      CALL OUTPLT
      WRITE (6,105) (NAME(I),I=1,6)
      READ (5,101)MORE
      IF(MORE.EQ.4) GO TO 4
  100 FORMAT (6A10)
  101 FORMAT (I2)
  102 FORMAT (F10.4,F10.1)
  103 FORMAT (F10.3)
  104 FORMAT (//)
  105 FORMAT (8X,*TRAP DESIGNATION*,4X,6A10)
  106 FORMAT (8X,*----*,* -----------*,///)
  107 FORMAT (5X,*TIME*,6X,*D TIME*,5X,*ANGLE*,5X,*D ANGLE*,6X,*ANGULAR
     1VELOCITY*,8X,*ENERGY*,6X,*OPEN*,//)
  108 FORMAT (5X,F5.2,12X,F8.1,56X,F5.2,/)
  109 FORMAT (15X,F5.4,17X,F4.1,12X,F7.2,10X,F7.2,/)
  110 FORMAT (1H1)
  111 FORMAT (6X,*TOTAL TIME = *,F6.4,* FOR ANGULAR ROTATION OF *,F8.2,
     1 DEGREES*)
  150  FORMAT (5F10.2)
  151  FORMAT (8F10.2)
  152  FORMAT (8F10.2)
  153  FORMAT(2F10.2)
       STOP
       END
```

APPENDIX C

IMPACT TESTING DEVICE

Impact Testing Device

For laboratory and field research work at Guelph University devices are needed from which one can obtain various desired energy ranges and observe their results at impact. The Small as well as the Large Mohawk were calibrated for this purpose and a number of different spring adjustments allow operating the traps at various energy ranges. The spring powered mechanism however is not too accurate and what is worse, it is not consistent. A spring may break or, due to frequent use, may set and of course as a result inaccuracies develop. In order to ease this problem, Mr. Lunn suggested the construction of a guillotine-like device which would not have to rely on springs, but in principle be only a certain predetermined mass falling freely through a predetermined height. This device would give accurate and consistent results. The design and construction of this device was then incorporated into the project.

Configuration of Device

This device utilizes the theory of a mass falling freely through a predetermined distance converting the mass' potential energy into kinetic energy. The main plate which moves in the vertical direction is supported by four brackets with each holding four steel roller bearings. These bearings travel in two vertically positioned channels. The maximum distance for free fall is 30 inches. The main plate weighs 5.9 pounds and three additional weights of each 5.0 pounds are available to obtain a total of 20.9 pounds. Several combinations of various heights of fall and weights yield an energy range of 23.6 in-lb - 627.0 in-lb.

Two anvil plates are available with different height (5.0 inches and 9.0 inches) to accomodate different size animals.

A scale divided into inches for each plate is mounted on the device to readily read off the amount of fall. From this reading the tables will give the appropriate energy in steps of 1/4 of an inch. The main plate can be released from various heights by a solenoid which can be activated by a self-return flip switch mounted on the base plate. Care must be taken not to overload the solenoid by depressing the switch for a longer period of time. (Accidental switch-on of the solenoid cannot occur due to the self-return switch.) The solenoid works on the conventional 115 volt system.

Energy Tables for Impact Testing Device

Detailed energy tables for testing were issued with the device to Dr. R. Walker, Department of Zoology, Guelph University. The following table shows available energy values for various combinations of weight and distance of total fall.

Energy Table

Force (lb)	Total Fall (in)	Energy (in-lb) (for maximum fall)
5.9	4.0	23.6
	8.0	47.2
	12.0	70.8
	16.0	94.4
	20.0	118.0
	24.0	141.0
	28.0	165.2
10.9	16.0	174.4
	18.0	196.2
	20.0	218.0
	22.0	239.0
	24.0	261.6
	26.0	283.4
	28.0	305.2
	30.0	327.0
15.9	22.0	349.8
	24.0	381.6
	26.0	413.4
	28.0	445.2
	30.0	477.0
20.9	24.0	501.6
	26.0	543.4
	28.0	585.2
	30.0	627.0

Calibration Test

Calibration tests on the device seemed necessary in order to insure that the theoretically obtained calculations, assuming free fall, are meaningful and any friction in the main plate during fall is negligible.

The objective of the test was to measure the actual time interval between release of the main plate and its contact with the anvil plate. The distance of fall was predetermined. For measuring the time interval, the following electronic counter was used:

- Beckman, Universal EPUT and TIMER, model 5230. The timing capacity was adjusted to measure intervals to 1/1,000 of a second.

The timer is equipped with two terminals, one of which upon being activated starts the counter while a subsequent signal to the second terminal will stop the counter. The two terminals were connected to and activated by two micro-switches which were positioned along one of the channels a distance apart equivalent to the desired height of fall. Mechanical contact was established between the main plate and the two micro-switches. The necessary power to the circuit was supplied by a conventional 0/30 V DC - 5A unit.

The tests were carried out at ten different heights from 4.0 inches to 30.0 inches and 12 readings were taken at each height. The experimental energy values were calculated and the largest deviation from theoretically established values was only 6%. This fact justified the initial theory and the use of calibration tables calculated by assuming free fall.

APPENDIX D

ANIMAL STATISTICS

Furbearing Animals Under Consideration

The present project deals with traps intended for three groups of animals which are categorized by their respective sizes. These three groups shall be defined and henceforth be referred to in the following manner:

Group I	Muskrat	Skunk	Snowshoe Rabbit
	Mink	Opossum	Civet Cat
	Marten	Groundhog	Small Fisher
Group II	Raccoon	Large Hare	Nutria
	Large Fisher	Badgers	
Group III	Beaver	Lynx	Wolverine
	Otter	Bobcat	

According to statistics gathered by Mr. F. Conibear, these three groups make up approximately 83% of all furbearing animals caught in Canada and the U.S.A. with:

Group I	73.27%
Group II	7.83%
Group III	2.05%

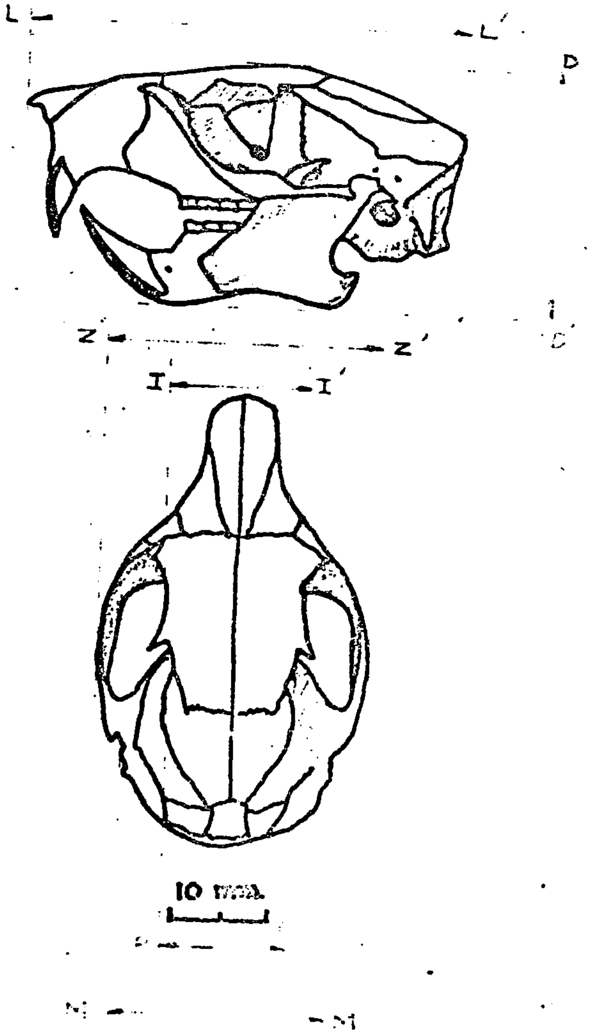
Dr. Robert Walker from the Zoological Department of Guelph University supplied a list of body size statistics of some of the above mentioned animals, as well as detailed skull dimensions. These statistics are listed on the following pages.

Furbearer Measurements & Weights

		Head & Body Length		Maximum Shoulder Height (cm.)	Maximum Shoulder Width (cm.)	Weight	
		Mean (cm.)	Range (cm.)			Mean (kg.)	Max. (kg.)
Red Squirrel		18.5	13.0-20.0	7.5	4.5	0.195	0.250
Short-tailed weasel	M	21.0	16.0-23.0	6.5	3.5	0.120	0.180
	F	17.5	12.5-19.0	- -	- -	0.065	0.075
Long-tailed weasel	M	25.0	14.0-28.0	10.0	4.5	0.220	0.265
	F	21.0	16.0-22.0	- -	- -	0.120	0.130
Mink	M	39.0	32.5-42.0	11.5	6.5	1.050	1.250
	F	32.0	25.0-34.0	- -	- -	0.750	0.950
Marten	M	41.0	33.0-45.5	13.0	9.5	0.900	1.500
	F	38.0	29.0-40.2	- -	- -	0.650	0.950
Muskrat		29.5	21.0-36.0	13.0	10.0	1.000	1.580
Raccoon		52.0	35.0-71.0	21.5	20.5	- -	14.930
Fisher	M	60.0	50.5-82.0	23.0	19.0	- -	5.225
	F	50.0	43.0-52.0	- -	- -	- -	2.465
Beaver		62.5	45.0-90.0	28.0	23.0	13.435	29.860
Otter		65.0	40.0-80.0	25.0	21.5	3.920	11.195

Skull Dimensions

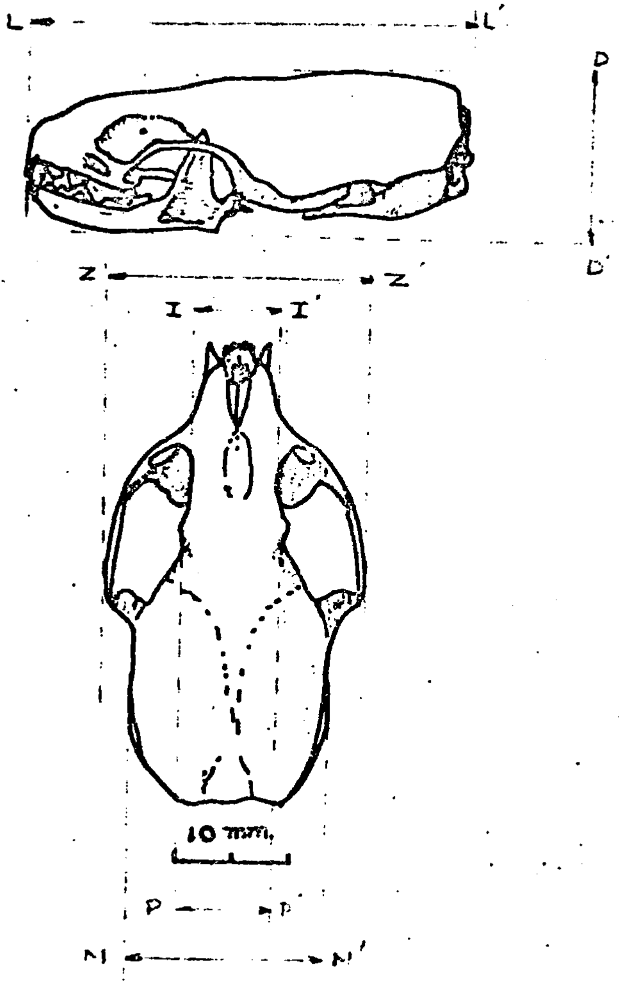
RED SQUIRREL (*Tamiasciurus hudsonicus*)



Measurements :

Skull length	LL'	42-49
Skull depth	DD'	24-26
Zygomatic width	ZZ'	24-28
Interorbital distance	II'	13 - 15
Post orbital constriction	PP'	13 - 16
Mastoid width	MM'	15 - 21

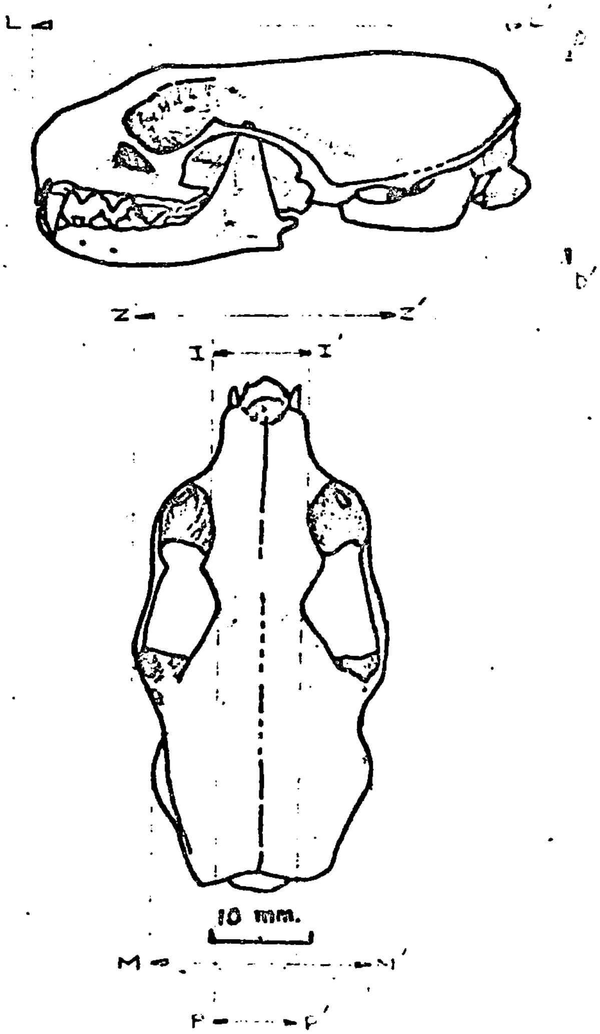
SHORT-TAILED WEASEL (Mustela erminea)



Measurements:

Skull length	LL'	34-47
Skull depth	DD'	12- 17
Zygomatic width	ZZ'	16·5 - 24
Interorbital distance	II'	8- 11
Post orbital constriction	PP'	8- 11
Mastoid width	MM'	16- 22

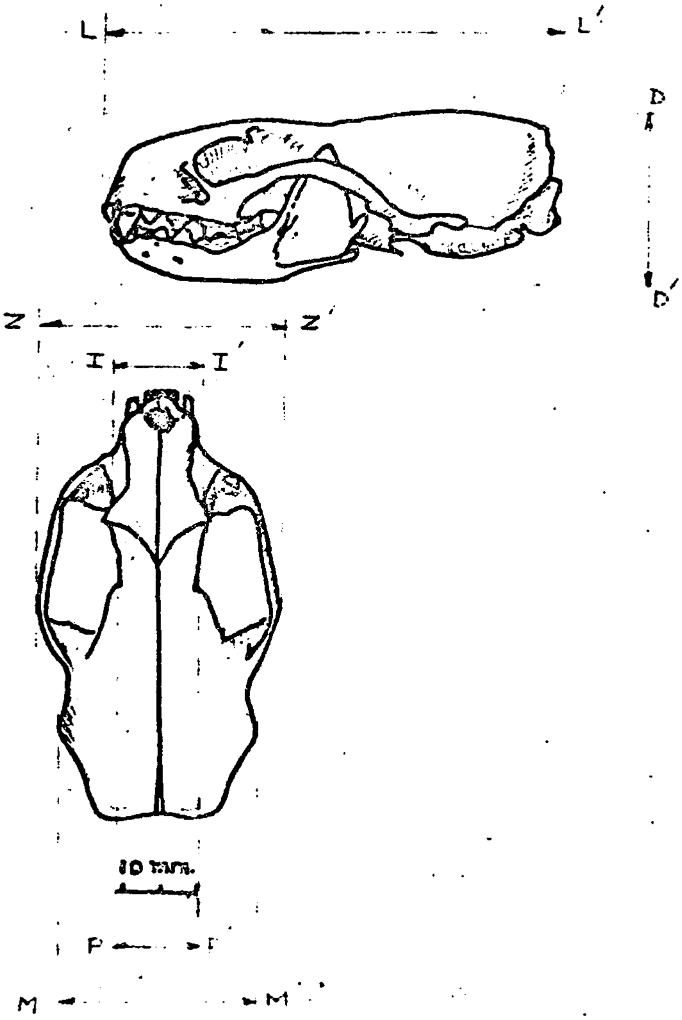
LONG-TAILED WEASEL (Mustela frenata)



Measurements:

Skull length	LL'	38-51
Skull depth	DD'	18 - 22
Zygomatic width	ZZ'	19 - 28
Interorbital distance	II'	9·5 - 12
Postorbital constriction	PP'	10 - 12·5
Mastoid width	MM'	21 - 27

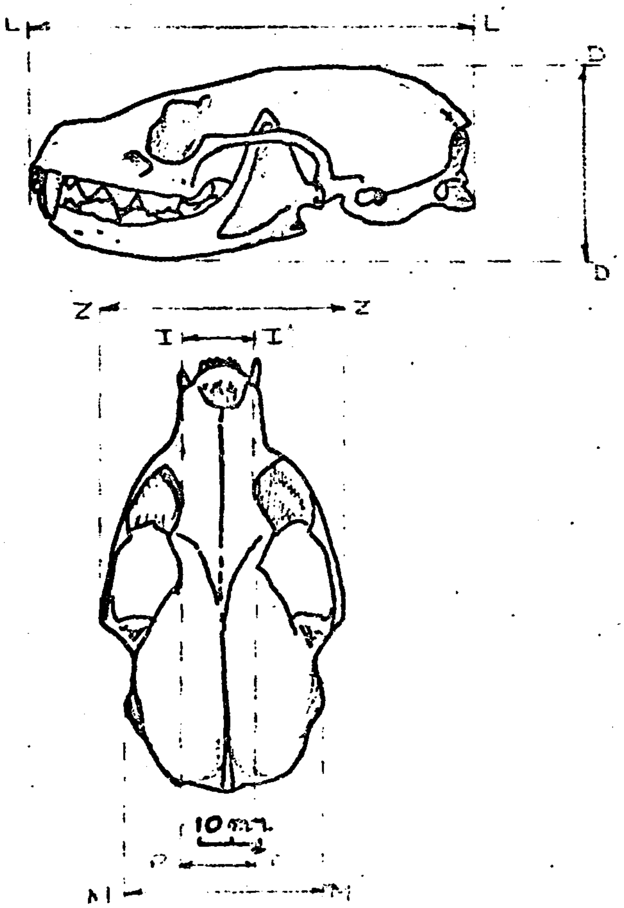
MINK (Mustela vison)



Measurements :

Skull length	LL'	58-70
Skull depth	DD'	21 - 29
Zygomatic width	ZZ'	31 - 43
Interorbital distance	II'	11 - 18
Post orbital constriction	PP'	11 - 14
Mastoid width	MM'	27 - 40

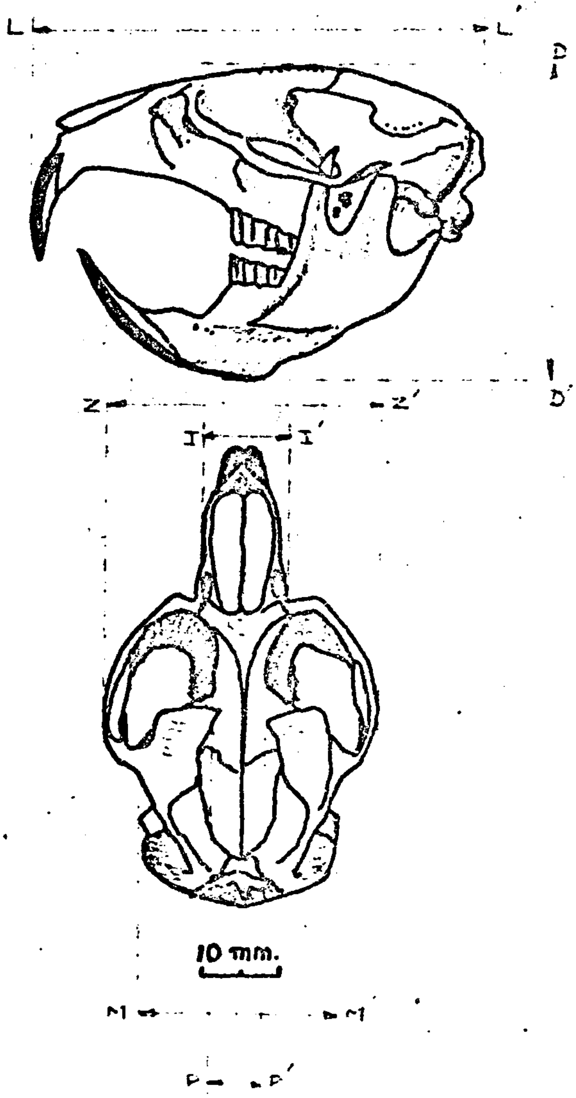
MARTEN (Martes americana)



Measurements:

Skull length	LL'	69 - 90
Skull depth	DD'	28 - 34
Zygomatic width	ZZ'	38 - 53
Interorbital distance	II'	15 - 19
Post orbital constriction	PP'	13 - 18
Mastoid width	MM'	32 - 38

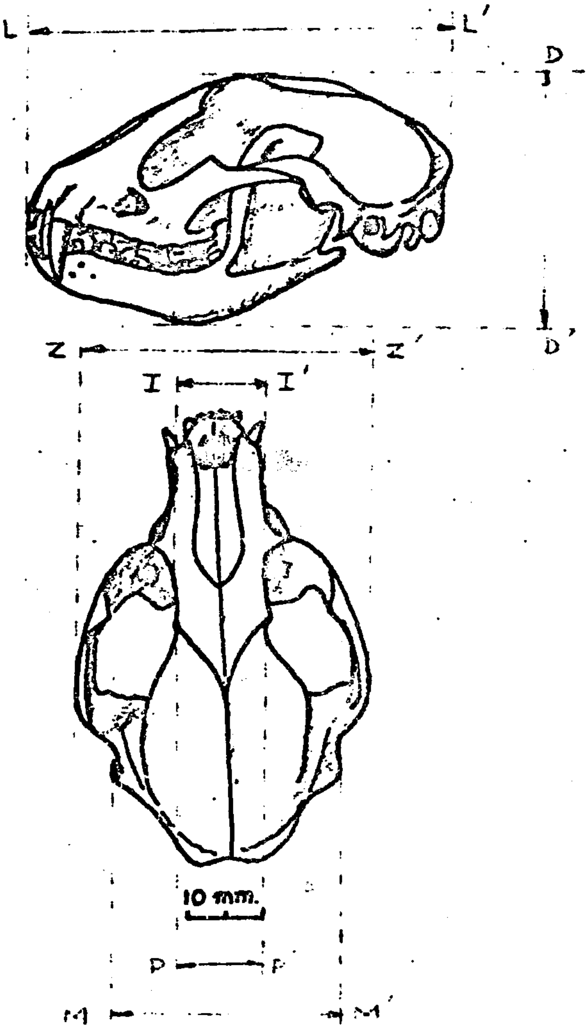
MUSKRAT (Ondatra zibethica)



Measurements:

Skull length	LL'	61 - 69
Skull depth	DD'	37 - 47
Zygomatic width	ZZ'	37 - 44
Inter orbital distance	II'	9 - 11
Post orbital constriction	PP'	5 - 7
Mastoid width	MM'	23 - 29

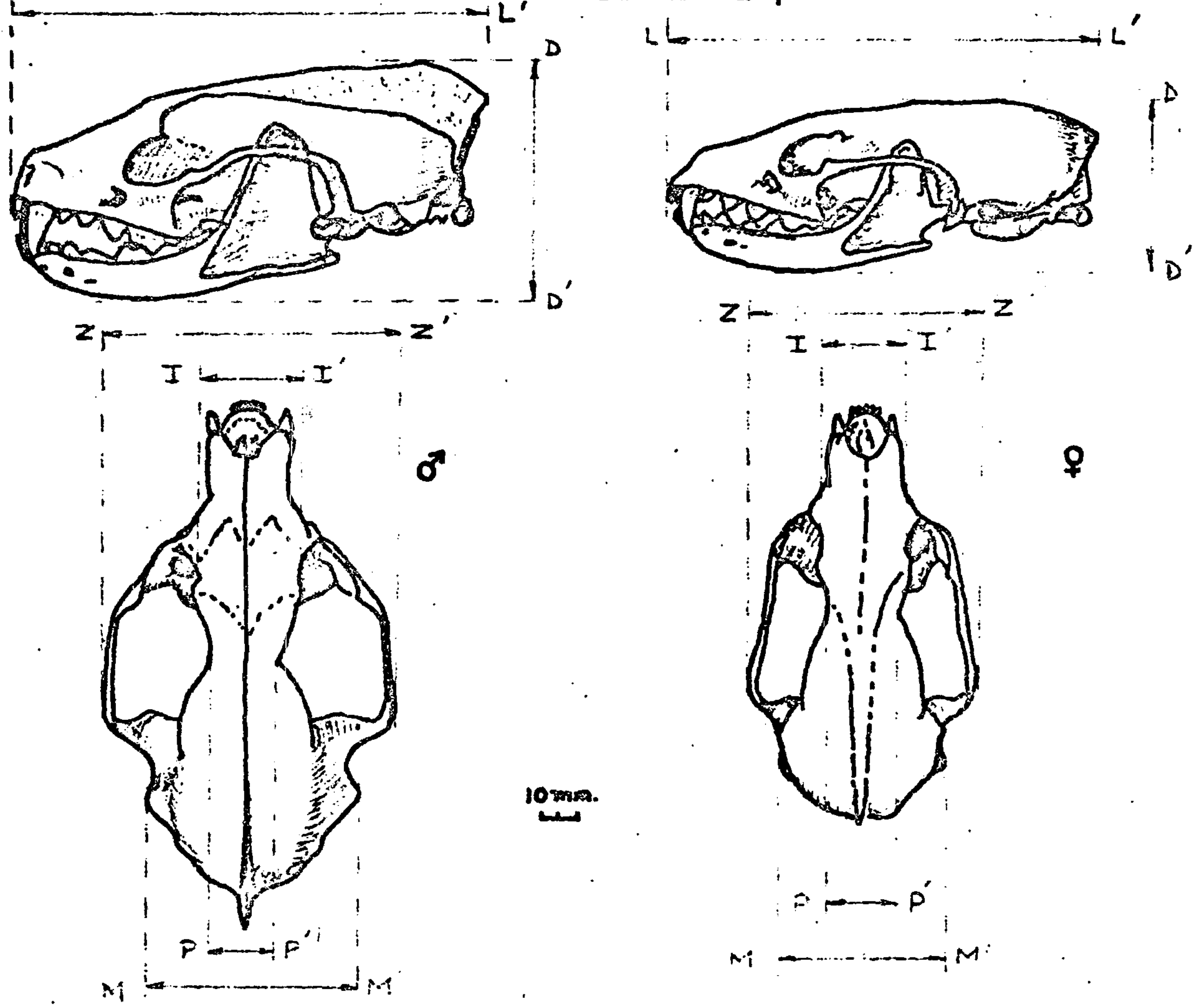
RACCOON (Procyon lotor)



Measurements :

Skull length	LL'	110 - 128
Skull depth	DD'	43 - 59
Zygomatic width	ZZ'	69 - 82
Interorbital distance	II'	20 - 25
Post orbital constriction	PP'	19 - 27
Mastoid width.	MM'	41 - 60

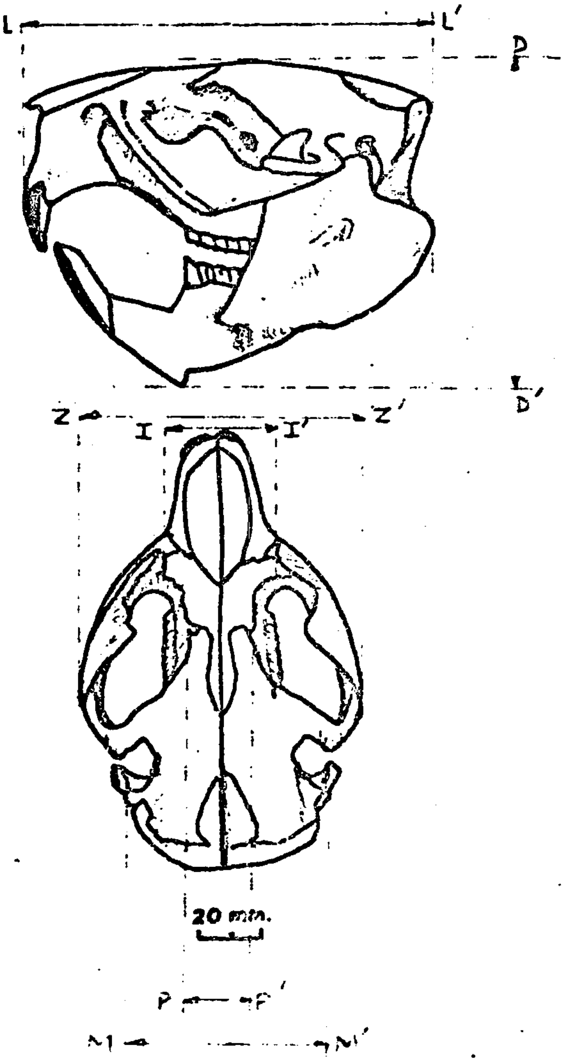
FISHER (Martes pennanti)



Measurements:

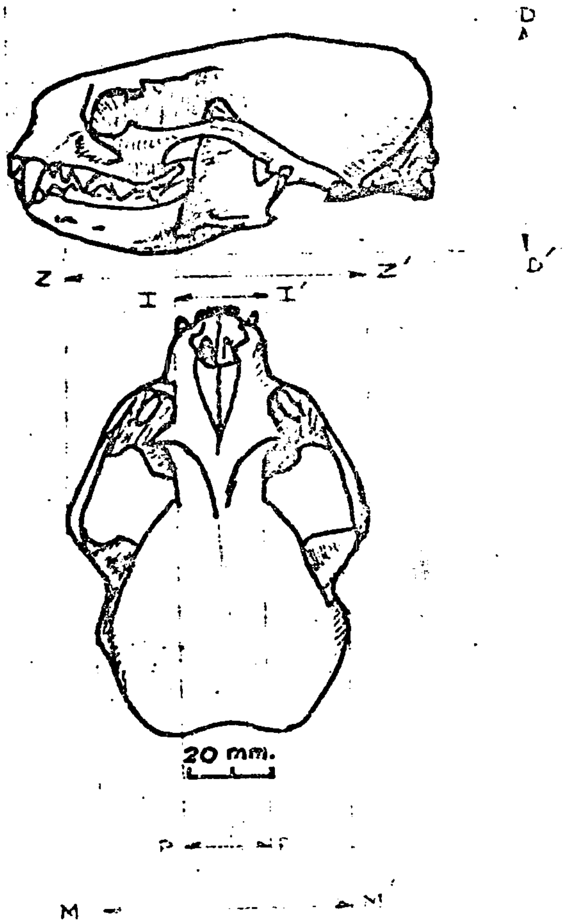
Skull length	LL'	95-130
Skull depth	DD'	40 - 60
Zygomatic width	ZZ'	52- 84
Interorbital distance	II'	21- 28
Postorbital constriction	PP'	17- 25
Mastoid width	MM'	43 - 57

BEAVER (Castor canadensis)



Measurements:

Skull length	LL'	119- 145
Skull depth	DD'	61 - 90
Zygomatic width	ZZ'	80 - 105
Interorbital distance	II'	25- 40
Post orbital constriction	PP'	19- 26
Mastoid distance	MM'	43- 66



Measurements:

Skull length.	LL'	95-120
skull depth.	DD'	41-50
Zygomatic width.	ZZ'	60-80
Interorbital distance.	II'	19-26
Post orbital constriction.	PP'	19-22
Mastoid width.	MM'	55-71

APPENDIX E

DESIGN EQUATIONS FOR FLAT CURVED SPRINGS

Definitions of Design Variables for Flat Curved Spring

T - deflection (in.)

k - correction factor (in our case $k = 0.95$)

F - spring force (lb.)

r - radius of curvature (in.)

u - length of straight section of free end of spring (in.)

m - u/r

B - angle of curvature (rad.)

s - section modulus (in our case $bh^2/6$ (in.^{3}))

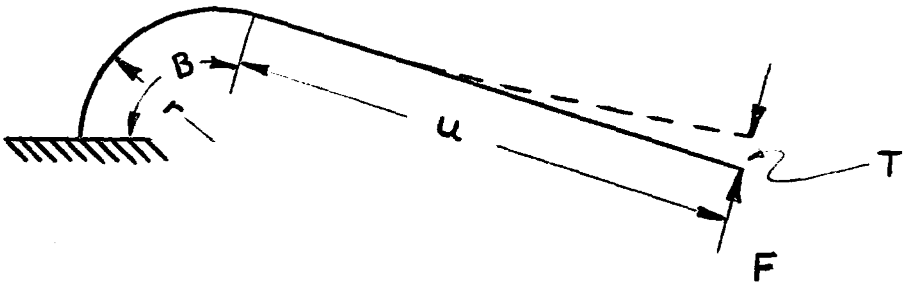
S - stress (in our case $S_{max} = 195{,}000$ psi)

E - Young's Modulus (3×10^7 psi)

I - area moment of inertia ($bh^3/12$) (in.^{4})

b - width of spring material (in.)

h - thickness of spring material (in.)



Design Equations for Curved Springs - The deflection of the spring is governed by:

$T = (m - B)^3 \, k \, F \, r^3 \, / \, 3 \, E \, I$ (1)

The stress in the spring is calculated by:

$S = Fr \, (m - 1) \, / s$ (2)

Solving equations (1) and (2) for F, equating both and solving for h, will yield the thickness of the spring material h, required in the spring design.

$h = (2 \, S \, k \, / \, 3 \, T \, E \,)M$, where

$M = (((L-r/.8098)/r - B)^3 \, r^{\,3}) \, / \, (L-r/.8098 -r)$

As soon as h is determined, the width of the spring material may be calculated depending on the force F which is desired at full deflection

$F = bh^2 \, S \, / \, 6 \, (u - r)$