FOOD INTERFACE WITH LINEAR SPRING MASS
OSCILLATOR MASS MEASUREMENT DEVICES

Accuracy of this mass measuring device is dependent upon the physical characteristics of the mass being measured. This can be readily appreciated by reference to the simplified block diagrams in Figure 1 Ia is the first order equivalent of the MMD, and Ib is the mass measuring device with a rigid solid mass to be measured. Ic is the MMD with a non-rigid unknown. Period of oscillation of the MMD alone or with rigid samples is approximated by:

$$T_o = \frac{1}{2\pi\sqrt{K_o / M_o}}$$

While that of the MMD with a non-rigid mass sample is:

$$T_x = \frac{1}{\pi\left[\frac{K_o}{M_o} + \frac{K_x}{M_x}\left(1+\frac{M_x}{M_o}\right) \pm \sqrt{\left[\frac{K_o}{M_o} + \frac{K_x}{M_x}\left(1+\frac{M_x}{M_o}\right)\right]^2 - \frac{4K_oK_x}{M_oM_x}}\right]}$$

Even if the unknown masses characteristics were as simple as this example, it obviously becomes unrealistic to attempt to cope with any sample which 'sloshes' appreciably. The above equation is given for steady state oscillations. Transient behavior of the system, i.e., immediately after release of the pan, is even more confusing. This problem was compounded when the contractor was allowed to reduce the number of counted cycles from 5 to 3.

Qualitatively, any non-rigid body will produce an error in mass when measured by the mechanically oscillating MMD's. The stiffer, i.e., the higher the natural frequency of oscillation of the sample, the less error. Since frequency of oscillation of the scale is low, on the order of one Hertz, objects with some slosh may be measured with acceptable error. An example is congealed puddings. Conversely, liquids in open containers of appreciable size will produce gross errors.

The problem is compounded under weightlessness by recent trends toward open food containers and by the packaging of solid items such as candies and nuts in rigid cans. Liquids, if handled carefully, may be constrained to their containers by surface tension; but once oscillated they will slosh and possibly be detached entirely from their containers.

The problem then is to constrain all liquids, semi-liquids and particulate solids in a fashion that couples their mass to the pan with high stiffness; i.e., the system to be measured must have a high resonant frequency and of course must be contained to prevent spillage under weightlessness. For example, water in a large flaccid bag will produce large errors; but in a taunt elastic bag or a bag with baffles will produce little error.

To see firsthand how serious the food problem was, Thornton and Kerwin obtained as many food types as possible and on March 12 made mass determinations with a prototype MMD that is in flight configuration. Only large cans (Size 208) without membranes were available for this first test.

Foods tested are listed in Table 1. Each food was measured under conditions as close to actual usage as possible; for example, hot or cold and typical quantities were removed from the cans.

The MMD was calibrated for the first run in the usual manner by leveling it such that its plane of oscillation was normal to gravity. Calibration masses were used to obtain period values which were rounded off to the fourth place, squared and the results plotted in Figure 2. The usual straight line approximation obtained was probably accurate to 0.5 gram.

First item tried was dried beef which was impossible to mass in the open can. After transfer to a plastic bag (this allowed accurate measurement) and other maneuvers, it was noted that the can top was a nice interference fit in the can body. This provided a simple solution and the results obtained in Table 1 were with the lid pushed firmly against can contents. Under 1-g, liquids of low viscosity leaked sufficiently to require a different procedure, but the leakage was low enough to allow such items as cream corn to be measured in a can lying on its side.

All can tops came away clearly without excess bending or distortion sufficient to interfere with a good fit of the top and can. Table IA shows the results obtained which are certainly more than adequate to meet medical requirements.

Although lids of the large cans provided a relatively tight seal, it was not liquid tight. Less viscous fluids would leak during mass determination unless the cans were upright. This required placing the scale 'on end' and running a new calibration scale. In this mode its behavior becomes more complex than the straight line approximation, so time was plotted as a function of mass and a curve empirically fitted (Figure 3). Liquid and liquid mixed items were run with and without the top pressed onto contents.

Tests under 1-g without the top for restraint would be unduly optimistic for gravity exerts a large restoring force which in effect makes the mass more rigid. Under weightlessness only surface tension is present as a small restoring force. Conversely, the can top provided tight enough fit for this mode to be representative of weightlessness accuracies. Table 2 gives the results.

Unfortunately only large cans without the plastic restraining sheet were available on the 12th. When large cans with plastic and smaller can sizes were available on 25th, a second trip was made by Thornton to S.W.R.I. to examine their behavior.

A different scale location and modification of the pan required another calibration (Curve 2 of Figure 2). Unfortunately the smaller can lid was 10 - 15 x 10^{-3} inches smaller in diameter than the can I.D. To get a fit tight enough to restrain can contents, it was necessary to squeeze and fiddle with the can. Again lid distortion or sharp edges presented no problem. The plastic sheet on the can, if what we had was a fair representation, would probably be more trouble than value both in food consumption and measurement. It was so tough that a very sharp knife was required to open it and more and messy effort was required to cut enough away to push the lid into the can. By judicious squeezing of the small cans it was possible to stabilize their contents enough to obtain the measurements shown in Table 2. Procedure for these measurements was the same as the first part of the measurements on March 12.

Results: In each case the results are more than adequate for medical studies. MMD's operated well and should give no trouble with reasonable care. It is obvious that the MMD's will become dirty in short order without some cleanup. Again the desirability of a separate precision scale for M074 is demonstrated, rather than trying to make a kitchen and crapper scale also function as a precision device. For that matter scales of different design for kitchen and crapper would have been more sensible.

S.W.R.I. have obtained fecal bags which are supposedly "flight configuration" and contain a large 'sponge' that expands several fold in thickness when wet, completely filling the bag. From an MMD viewpoint this is excellent, but the procedure may be less comforting to a crewman with diarrhea for the sponge expands rapidly and completely fills the bag. MMD results with simulated fecal material were excellent with these bags.

Conclusions: If the large food cans used for flight are made with the same tolerances as the samples tested, it will be possible to measure all food residues with more than sufficient accuracy by the quick and simple expedient of pushing the can top firmly into the can where it stabilizes the contents. This assumes that no more than 60 - 70% residue. Depending upon the consistency of plastic restraining sheets on the can, they will cause more or less trouble in removal in order to insert the tops.

The small cans, as currently produced, required bending to make the tops fit tightly enough to restrain contents; but once done the accuracies are acceptable. Closer fit of lid and can are desirable.

Fecal bag errors, using the expanding sponge of the "latest configuration" are also acceptable with simulated fecal material; but their utility in actual diarrhea should be demonstrated unless the sponge is inserted after use.

Testing of the drink container and main and contingency urine bags will be performed when the containers are available.

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TABLE 1

MASS DETERMINATION OF FOOD RESIDUE
IN LARGE CANS ON MARCH 12, 1971

A. MMD oscillation plane normal to gravity

FOOD	MMD PERIOD/SEC	MASS MMD GMS	MASS GRAVIMETRIC GMS	ERROR GMS
Sliced Dried Beef	2.071	53.0	51.4	+ 1.6
German Potato Salad	2.093	67.2	67.2	0.0
Sausage Patties	2.056	41.5	40.5	+ 1.0
Vienna Sausage	2.097	71.0	70.1	+ 0.9
Pork & Scalloped Potatoes	2.109	79.0	77.6	+ 1.4
Cream Style Corn	2.108	78.5	77.1	+ 1.4
Apple Sauce	2.094	69.8	68.4	+ 1.4
Meat Balls & Sauce	2.065	48.8	48.1	+ .7
Spaghetti & Sauce	2.150	108.0	107.4	+ .6
Beef & Gravy	2.126	91.0	89.7	+ .3

B. MMD oscillation plane parallel to gravity

FOOD	MMD PERIOD/SEC	MASS MMD GMS	MASS GRAVIMETRIC GMS	ERROR GMS
Shrimp Cocktail	4.925	91.9	90.8	+ 1.1
Peaches in Syrup	4.725	66.5	65.8	+ .7
Chili Con Carne	5.195	108.0	107.8	+ .2
Mustard	5.270	111.8	110.7	+ 1.1
Catsup	5.284	113.0	111.1	+ 1.9
Veal & BBQ Sauce	4.752	81.3	81.6	- .3
Potato Soup[1]	5.117	103.8	104.6	- .8
Lobster Newberg	4.523	66.3	66.9	- .6
Chicken Soup	5.377	118.0	119.3	- 1.3

[1]Possible MMD error through spillage.

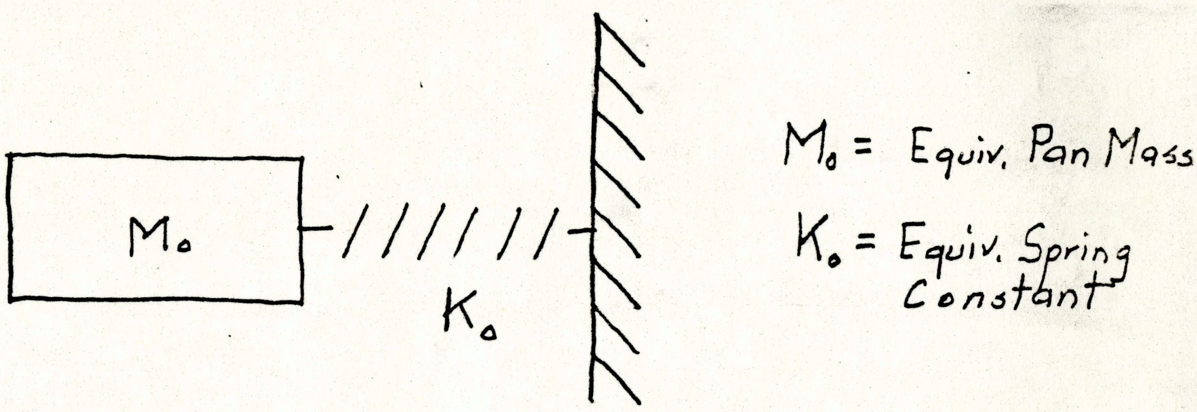
TABLE 2

MASS DETERMINATION OF FOOD RESIDUE IN SMALL CANS ON MARCH 25, 1971

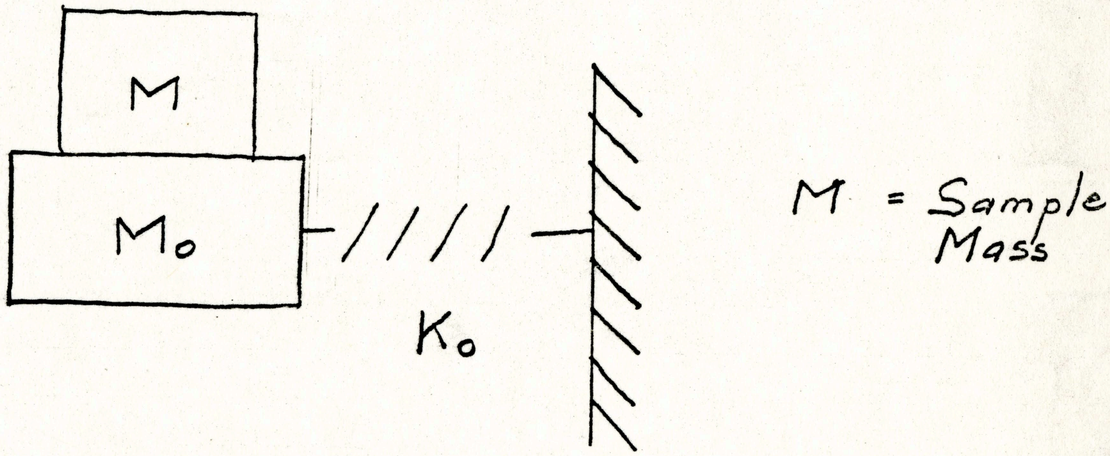
FOOD	MMD PERIOD/SEC	MASS MMD GMS	MASS GRAVIMETRIC GMS	ERROR GMS
Roasted Peanuts	1.993	32.7	31.9	+ 0.8
Soda Crackers	1.984	25.8	26.0	- 0.2
Butter Cookies	1.981	24.8	24.4	+ 0.4
Cheese Crackers	1.973	19.5	19.0	+ 0.5
Melba Toast	1.980	24.2	23.8	+ 0.4
Ham Salad	2.022	51.6	51.1	+ 0.5
Dried Apricots	1.986	28.3	28.0	+ 0.3
Ham	2.025	54.0	53.5	+ 0.5
Vanilla Wafers	1.972	18.7	18.9	+ 0.2
Apple Currant Jelly	2.043	66.5	65.2	+ 1.3
Gumdrops	2.014	46.6	46.5	+ 0.1
Applesauce[2]	2.104	107.0	106.0	+ 1.0
Chili[2]	2.126	120.7	121.9	+ 1.2

[2]In large cans

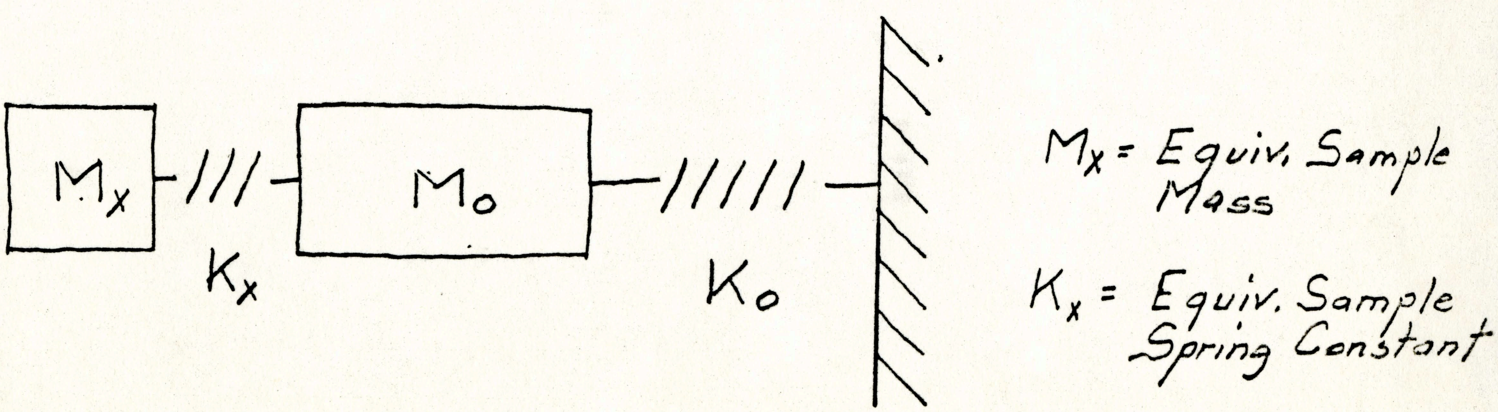
Fig. 1



a. First Order Approximation of MMD



b. Approximation of MMD and rigid sample



c. Approximation of MMD and non-rigid sample

Fig. 2

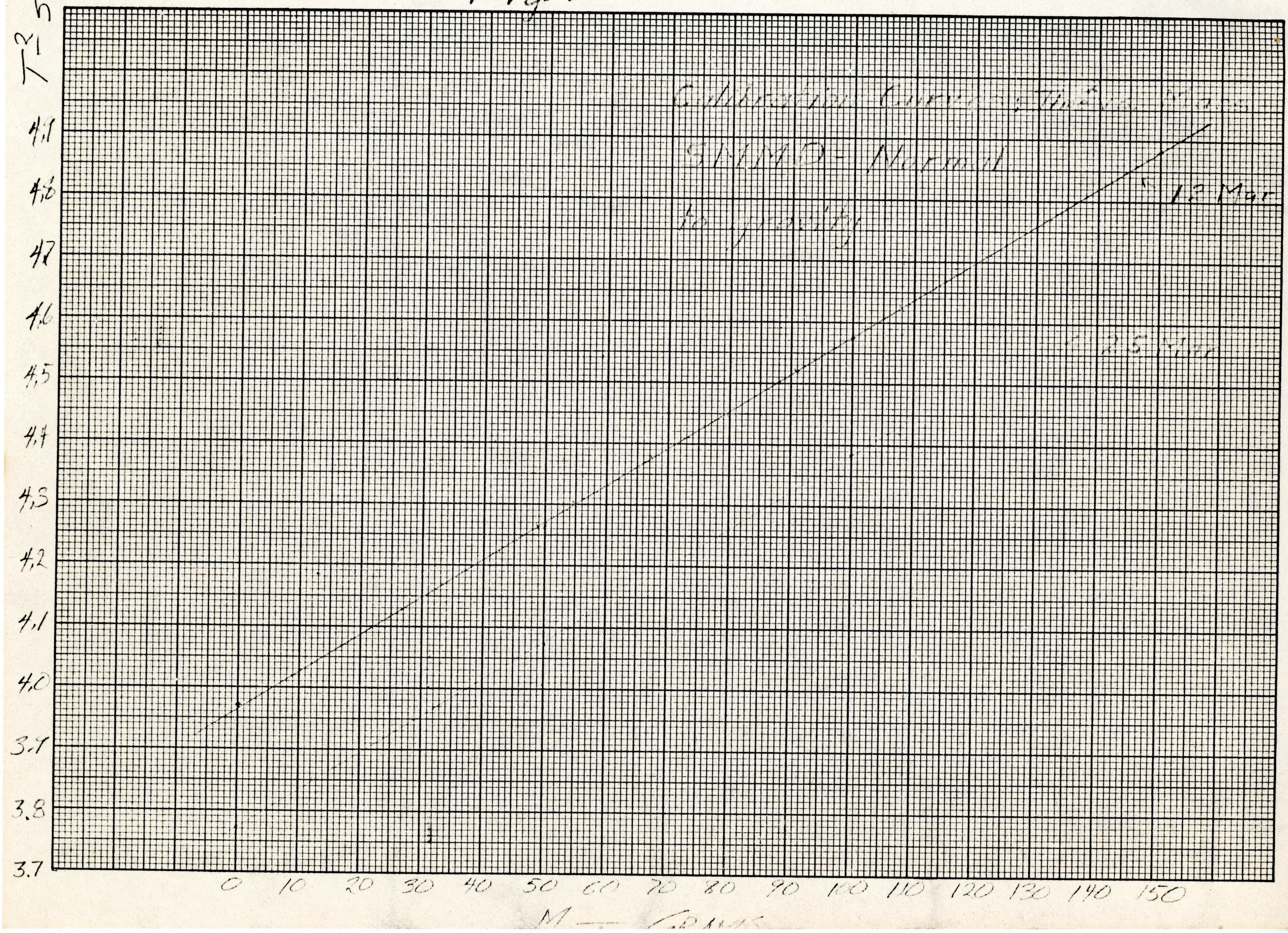

3.7
3.8
4.0
4.1
4.2
4.3
4.5
4.6
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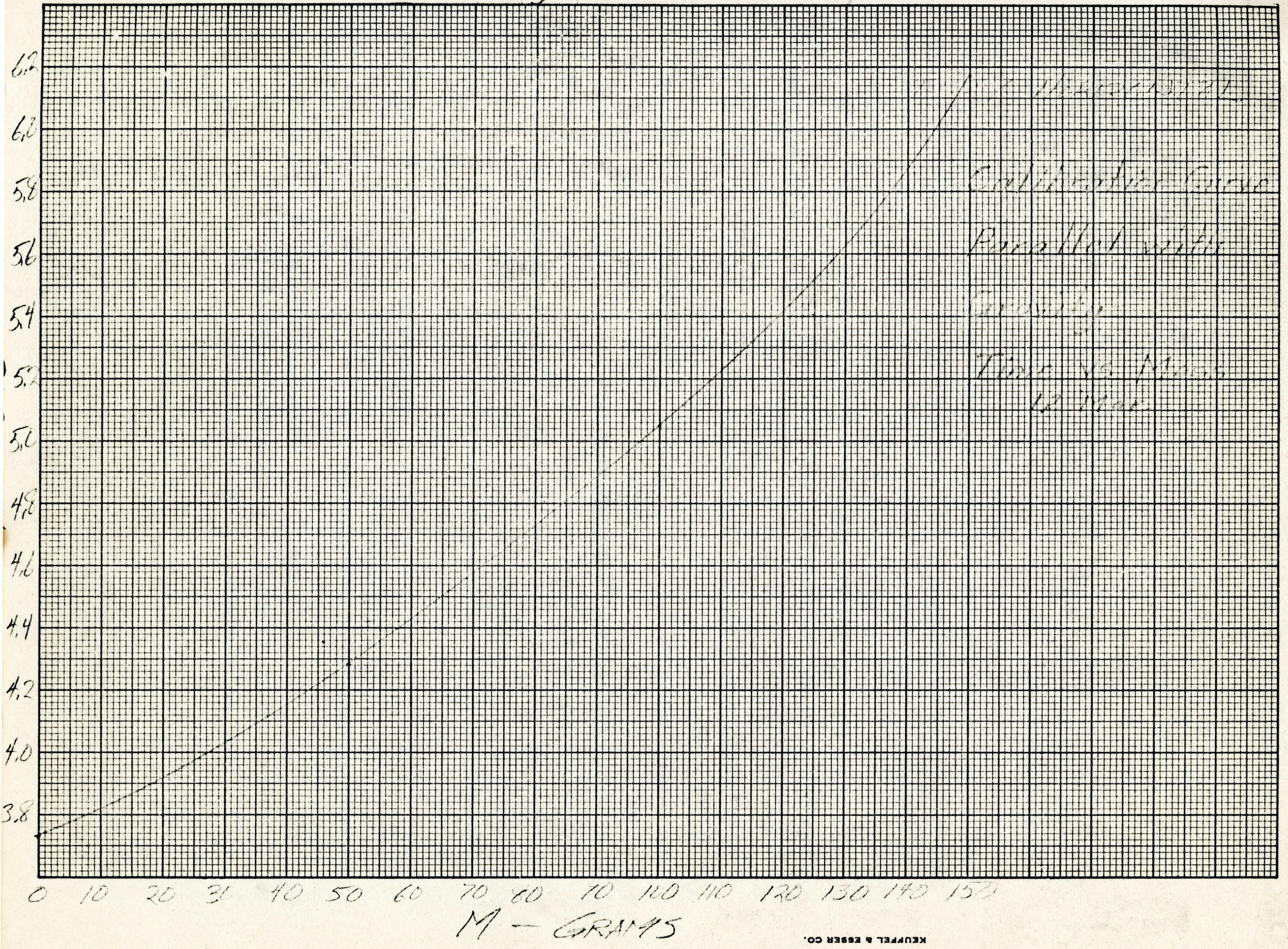
Fig. 3


6.2
6.0
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
M – GRAMS
Calibration Curve
Parallel with
Gravity
Time vs Mass
12 Mar.