Report No. CDOH-DTP-R-84-19

PYCNOMETER SHAKER

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Final Report
September 1984

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
CDOH-DTP-R-84-19		

4. Title and Subtitle	5. Report Date
Pycnometer Shaker	September 1984
	6. Performing Organization Code 1483-A
7. Author(s) Robert Somrak, William Whittaker	8. Performing Organization Report No. CDOH-DTP-R-84-19
9. Performing Organization Name and Address Colorado Department of Highways 4201 E. Arkansas Ave. Denver, CO. 80222	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 1483-A
12. Sponsoring Agency Name and Address Colorado Department of Highways 4201 E. Arkansas Ave. Denver, CO. 80222	13. Type of Report and Period Covered Final 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in Cooperation with the U.S. DOT, Federal Highway Administration

16. Abstract A mechanical shaker, to provide a standard shake for the pycnometer test for asphalt cement content of an asphalt concrete mix was built and tested. Test results with mechanical shaker indicate slightly higher specific gravities as compared to the manual shake. This indicated that more of the entrained air is removed with the mechanical shake. The shaker dramatically improved consistency of the pycnometer test results and eliminated the need for calibration of each individual tester.

Implementation

This shaker is being used by the District III Materials Lab and is recommend for use in other labs throughout the state.

17. Key Words	18. Distribution Statement
Pycnometer, Asphalt Content, Extrained Air	No restrictions. This document is available to the public through the National Technical Information Service/Springfield, Virginia. 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	21	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENTS

The author would like to thank all of the Department of Highways personnel who helped in doing this research project.

Special appreciation for work and input contributed to this report is expressed to Bill Whittaker, District III Laboratory.

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INTRODUCTION

The pycnometer method of asphalt content determination has been adopted by the Colorado Department of Highways. This method was adopted to help reduce the use of methylene chloride (both a health hazard and expensive) associated with the vacuum extractor. One problem with the pycnometer method is consistency in removal of entrapped air in the asphalt mix sample by hand shaking. Each tester is required to obtain their own calibration due to individual shaking methods. Even the same tester can obtain differing results due to fatigue or illness causing a difference in shaking methods. This project was designed to develop and refine a mechanical shaker to obtain consistency in the removal of entrapped air in the pycnometer.

SHAKER DESIGN AND CONSTRUCTION

The original proposal was to design, build and test a mechanical shaker and a vibration shaker. The mechanical shaker was built and initial tests taken and the design concepts were started on the vibration shaker. Due to the positive initial results from the mechanical shaker and the higher probable complexity, construction difficulty, and cost of the vibration shaker, it was decided not to build a vibration shaker. A second mechanical shaker of similar design, but easier to construct than the first mechanical shaker, was then designed and built.

TEST PROCEDURES AND RESULTS

Before field use of the pycnometer, each tester must calibrate the pycnometer for the asphalt and aggregate being used. During calibration, the specific gravity of the aggregate is determined. Colorado Test Procedure CP-42 Method C (see Appendix A) for the pycnometer requires four calibration tests for the aggregate specific gravity to have a maximum range of .005. A .005 range of the aggregate specific gravity is equal to approximately .1% asphalt. This aggregate specific gravity calibration test was used to determine the effect the shakers have on test results. Three testers were used with each person doing both manual and mechanical shaker tests. Aggregates and asphalt samples from the same source and production were used throughout the tests.

The shaker shown in Appendix B was the first one built. The combination of the up and down motion produced by the eccentric shaft and the four springs on the spring plate produce an orbital up and down motion. The operating speed of the shaker was obtained by visual observation of the mix during shaking. The pycnometer was filled to working weight with asphalt mix and water and placed in the shaker. The desirable operating rpm of the eccentric shaft was then determined using a variable speed motor. An eccentric shaft speed of 850 rpm seemed to give good shaking of the mix but kept the shaker relatively quiet. Some speeds produced harmonics where the mix was either not being affected or the shaker would attempt to self destruct. Two operators used this shaker with the results shown on page 5. Both operators obtained four test results with the specific gravity of the aggregate within a .005 range. Average specific gravities of 2.619 and 2.618 with the shaker show that each operator would not have to do individual calibration for this mix. Neither operator obtained four test results within a .005 range with hand shaking.

A second mechanical shaker was constructed that used a hinge assembly instead of the spring plates. This shaker was easier to build but only provided an up and down motion. The best eccentric shaft operating speed for this shaker was again determined to be about 850 rpm but at any speed, the hinge shaker seemed more violent and noisy than the spring plate shaker and it was felt the shaker would wear out quickly with much use. A third operator used this shaker and the results are shown on page 5. The standard method used by each operator was as follows: at each two minute interval during the 10 minute test period, turn on the shaker and rotate the pycnometer 90° on its side until the sample slumps to the side of the pycnometer, then rotate the pycnometer 180° until the sample slumps to the other side, release the pycnometer and turn off the shaker until the end of the next two minute period.

CONCLUSIONS AND IMPLEMENTATION

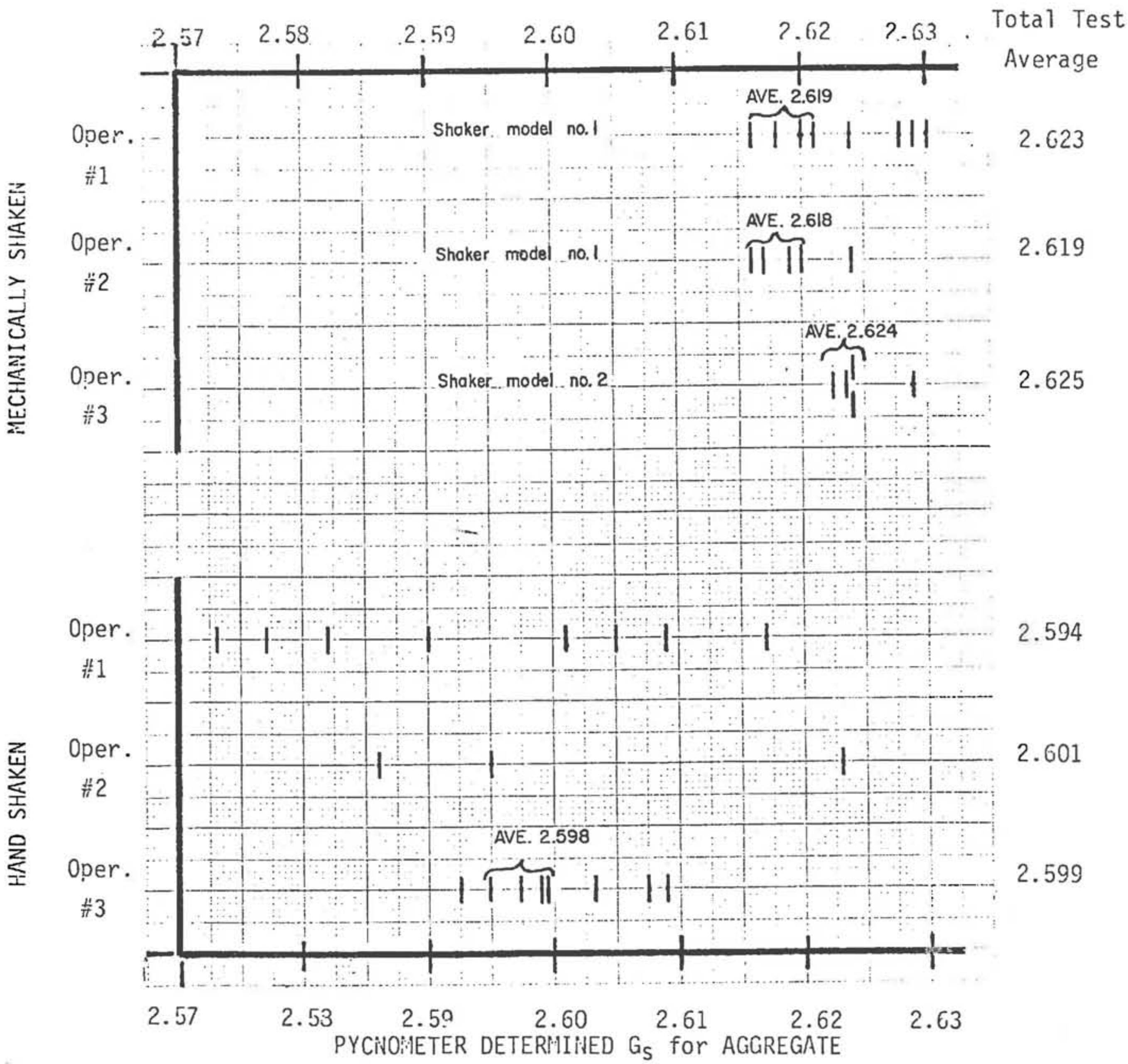
The results shown on page 5 for hand and mechanical shaking are not encouraging for use of the pycnometer without a shaker.

All three operators were careful to use the same techniques throughout the hand shaking tests but the test results varied widely.

A consistently higher specific gravity is obtained using mechanical shaking as opposed to hand shaking. This indicates more entrapped air is being removed from the sample with the mechanical shaker; this is critical to the test procedure. The hinge shaker produces a higher specific gravity than the spring shaker, probably due partly to a more violent shaking action. The three specific gravity averages for the mechanical shakers have a range of .006 which indicates the shakers give consistent and adequate inter-operator results and multiple calibrations should not be necessary. The results also show a high increase in single operator accuracy.

Both shakers are now being used by District III field testers on active construction projects with satisfactory results.

COMPARISON OF OPERATOR CONSISTANCY USING HAND and MECHANICAL MEANS OF AGITATING THE PYCNOMETER AND SAMPLE.



Object of testing was to obtain 4 tests within a range of .005 G_s for each operator. An error of .005 G_s for the aggregate will result in an error of 0.1% A.C. Content.

Mechanical Shaker #2 utilized an up and down motion for agitation.

Mechanical Shaker #1 utilized an orbital up and down motion for agitation.

All three operators had no previous experience with the Pycnometer Apparatus.

APPENDIX A

CP-42 Method C

CALCULATIONS

15.1 Weigh to the nearest 0.1 g, subtract the weight of the pan and filter and determine the percentage of bitumen extracted as follows:

$$\text{Bitumen content of dry mix specimen, percent} = \frac{(A-B) - C}{A-B} \times 100$$

where:
A = weight of test specimen
B = weight of water in specimen
C = weight of extracted aggregate

15.2 Add the retention factor previously determined by CP-40 to the percent bitumen extracted, and report the total as percentage of bitumen in the mix. Where the retention factor is known to be 0.04 percent or less, it may be disregarded.

NOTE 8: See example of DOH Form No. 578 and calculations in Chapter 400.

SIEVE ANALYSIS

16.1 If a sieve analysis of the extracted aggregate is desired, it shall be determined in accordance with CP-31, except that the size of the test specimen shall be determined in accordance with Table II, Section 13.

METHOD C - PYCNOMETER

APPARATUS

17.1 Large size plastic pycnometer having a capacity of at least 10,000 ml.

17.2 A suitable vacuum connection assembly consisting of a vacuum gage, release valve and tubing connector, a tapered stopper device for maintaining consistent volume regulation, a 1000 ml water trap made of plastic to withstand partial vacuums, thermometer with a range of 10 to 65 C and mixing bowls large enough to mix 6000 g samples.

17.3 A balance capable of weighing 20 kg to an accuracy of 1 g.

17.4 A vacuum pump or water aspirator capable of evacuating air from the pycnometer. The pump or aspirator must provide a partial vacuum of 660 mm Hg at sea level reading on a vacuum gage.

17.5 6.3 mm I.D. tubing, approximately 183 cm.

DETERMINATION OF THE SPECIFIC GRAVITY OF THE AGGREGATE

NOTE 2: This specific gravity is determined only once for each source or when a significant change in the gradation occurs. It will be determined by the project tester.

18.1 Prepare four aggregate specimens, (about 5500 g each) representative of the material to be used, by drying to a constant weight at 135 C $\pm$ 5.

18.2 Place the aggregate in a tared mixing bowl and weigh.

18.3 Immediately add asphalt cement (preheated to 135 C) of the amount and type specified in the job mix formula.

18.4 Thoroughly mix the asphalt cement and aggregate by hand until all aggregate is coated.

18.5 Repeat 18.2 through 18.4 to remaining specimens. Proceed to 20.1 through 21.1 to determine specific gravity of the mix; Gm.

NOTE 3: The specific gravity of the premixed samples, Gm, must be determined before the specific gravity of the aggregate, Ga, can be determined. Ga is determined in 19.1.

CALCULATION OF SPECIFIC GRAVITY OF AGGREGATE

19.1 $$Ga = \frac{Gm\ Gb\ (100 - P)}{100\ Gb - Gm\ P}$$

where:
Ga = specific gravity of aggregate
Gm = specific gravity of mix
P = known asphalt content
Gb = specific gravity of asphalt cement

NOTE 4: See example of DOH Form No. 563 and calculations in Chapter 400 in the Materials Manual.

PROCEDURE

20.1 The test can be made on cold or hot samples. For a cold sample, separate the particles, being careful not to fracture the mineral particles, so that the fine aggregate portion is not larger than 6.4 mm.

NOTE 5: If the mixture is difficult to manipulate, place it in a large flat pan and warm until it can be separated manually.

20.2 Place the sample in the pycnometer and weigh. Designate the net weight as a. With the lid on, fill the pycnometer to a point approximately 5 cm below the top.

20.3 Remove the entrapped air by subjecting the contents to a partial vacuum of 630 mm Hg reading on a vacuum gage for 10 minutes, $\pm$ one minute. To help release the entrapped air, vigorously shake the pycnometer at 2 minute intervals.

NOTE 6: 555 mm Hg is the required vacuum at 5000 feet above sea level. The vacuum must be corrected at various altitudes for changes in atmospheric pressure. Therefore, the partial vacuum required will increase or decrease 21 mm Hg per 1000 feet of increase or decrease in elevation above or below 5000 feet.

Example: When the test is performed at 8000 feet above sea level, the required corrected partial vacuum would be 492 mm Hg ([8000 - 5000] / 1000 X 21 mm Hg = 63 mm Hg, 630 mm Hg - 63 mm Hg = 492).

20.4 Immediately after the removal of entrapped air, fill the pycnometer with water, insert the vented stopper, dry the outside, and determine the weight. Designate the weight as g (sample and pycnometer filled with water). Remove the stopper and measure the temperature.

CALCULATION OF SPECIFIC GRAVITY OF MIX

21.1 $$Gm = \frac{a}{a + f - g + h} \times \frac{dw}{.9970}$$

where:

Gm = specific gravity of mix
a = weight of sample in air, g
f = weight of pycnometer filled with water at test temperature, taken from Figure 1, g
g = weight of pycnometer filled with water and sample at test temperature, g
h = correction for thermal expansion of asphalt, g, from Figure 2
$\frac{dw}{.9970}$ = multiplier, from Figure 3
dw = density of water at test temperature, Mg/m^3
.9970 = density of water at 25 C, Mg/M^3

NOTE 7: At completion of calculation refer to 19.1 to determine Ga for each premixed specimen. The average of the four will be considered the specific gravity of the aggregate, Ga. See example of DOH Form No. 563 and calculations in Chapter 400 in the Materials Manual. The acceptable range for the four trials shall be no greater than .005.

CALCULATION OF PERCENT ASPHALT CONTENT

22.1 $$P = \frac{100\,Gb}{Ga - Gb}\left(\frac{Ga}{Gm} - 1\right)$$

where:

P = percent asphalt content
Ga = specific gravity of aggregate
Gb = specific gravity of asphalt cement
Gm = specific gravity of mix

NOTE 8: See example of DOH Form No. 563 and calculations in Chapter 400 in the Materials Manual.

(CALIBRATION OF PYCNOMETER, Paragraphs 23.1 thru 23.4 appear in District Materials Guide Manual.)

NOTE 9: A moisture correction is necessary for mixes containing more than 0.10% absorbed moisture. Moisture will be determined according to Paragraph 3.1.

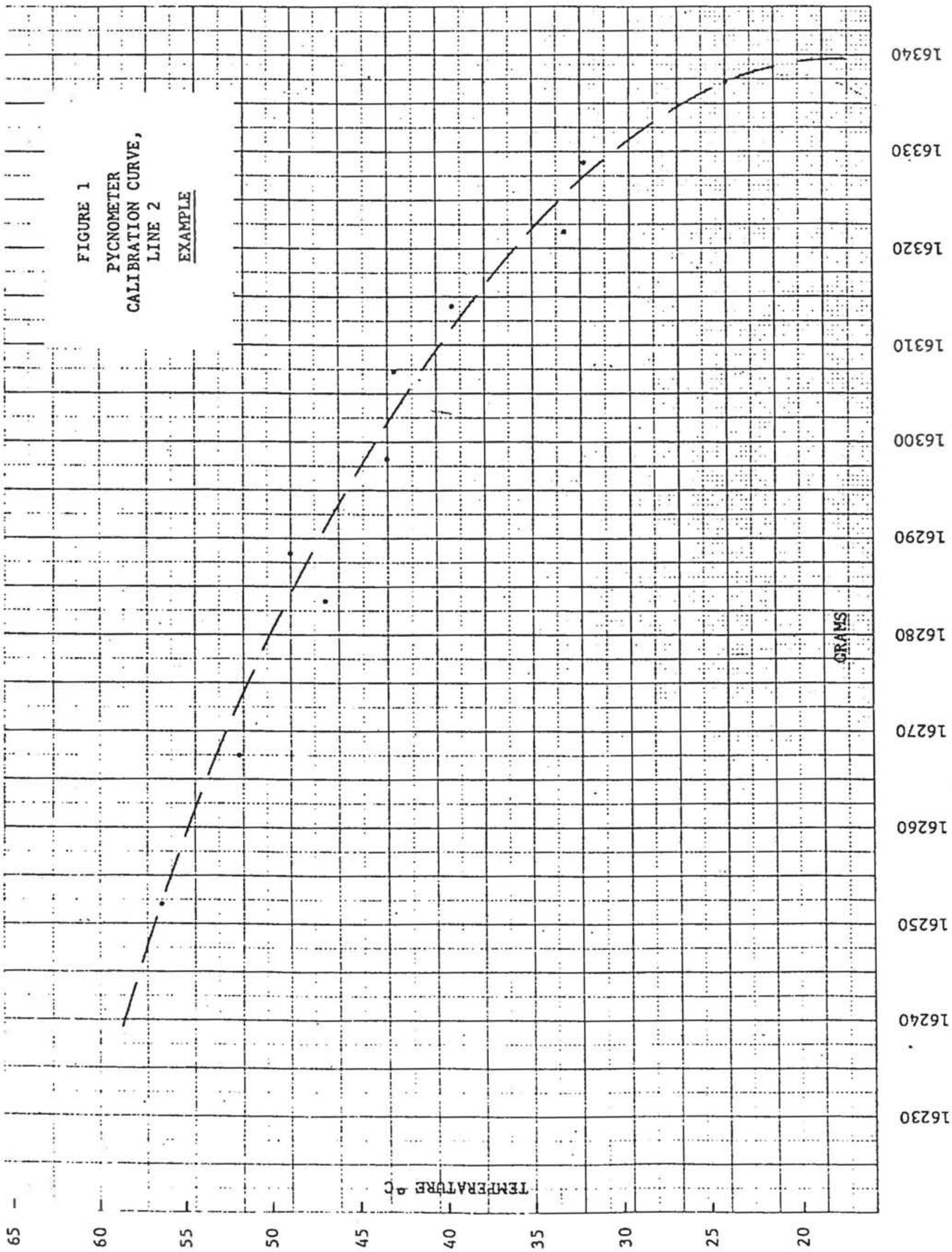


FIGURE 1
PYCNOMETER
CALIBRATION CURVE,
LINE 2
EXAMPLE

CORRECTION FOR ASPHALT EXPANSION, h, LINE 7 PYCNOMETER

Temp	Grams Asphalt in Sample					
°C	300	320	340	360	380	400	420

Temp °C	300	320	340	360	380	400	420
20	.6	.6	.7	.7	.8	.8	.9
21	.5	.5	.5	.6	.6	.6	.7
22	.3	.4	.4	.4	.5	.5	.5
23	.2	.2	.3	.3	.3	.3	.3
24	.1	.1	.1	.1	.2	.2	.2
25	.0	.0	.0	.0	.0	.0	.0
26	-.1	-.1	-.1	-.1	-.1	-.1	-.2
27	-.2	-.2	-.2	-.2	-.3	-.3	-.3
28	-.3	-.3	-.3	-.4	-.4	-.4	-.5
29	-.4	-.5	-.5	-.5	-.5	-.5	-.6
30	-.5	-.6	-.6	-.6	-.6	-.7	-.7
31	-.6	-.6	-.7	-.7	-.8	-.8	-.9
32	-.7	-.7	-.8	-.8	-.9	-.9	-1.0
33	-.8	-.8	-.9	-.9	-1.0	-1.0	-1.1
34	-.9	-.9	-1.0	-1.0	-1.1	-1.2	-1.2
35	-.9	-1.0	-1.1	-1.1	-1.2	-1.3	-1.4
36	-1.0	-1.1	-1.1	-1.2	-1.3	-1.4	-1.5
37	-1.1	-1.2	-1.2	-1.3	-1.4	-1.5	-1.6
38	-1.2	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7
39	-1.2	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8
40	-1.3	-1.4	-1.5	-1.6	-1.7	-1.8	-1.9

FIGURE 4

PYCNOMETER

TEMPERATURE °C	MULTIPLIER LINE 9 dw/.9970	TEMPERATURE °C	MULTIPLIER LINE 9 dw/.9970
15	1.0021	41	.9949
16	1.0020	42	.9945
17	1.0018	43	.9941
18	1.0016	44	.9937
19	1.0014	45	.9933
20	1.0012	46	.9928
21	1.0010	47	.9924
22	1.0008	48	.9920
23	1.0006	49	.9915
24	1.0003	50	.9910
25	1.0000	51	.9906
26	.9998	52	.9902
27	.9995	53	.9897
28	.9993	54	.9892
29	.9990	55	.9887
30	.9987	56	.9882
31	.9984	57	.9877
32	.9981	58	.9872
33	.9977	59	.9867
34	.9974	60	.9862
35	.9971	61	.9857
36	.9967	62	.9852
37	.9964	63	.9847
38	.9960	64	.9842
39	.9956	65	.9836
40	.9952		

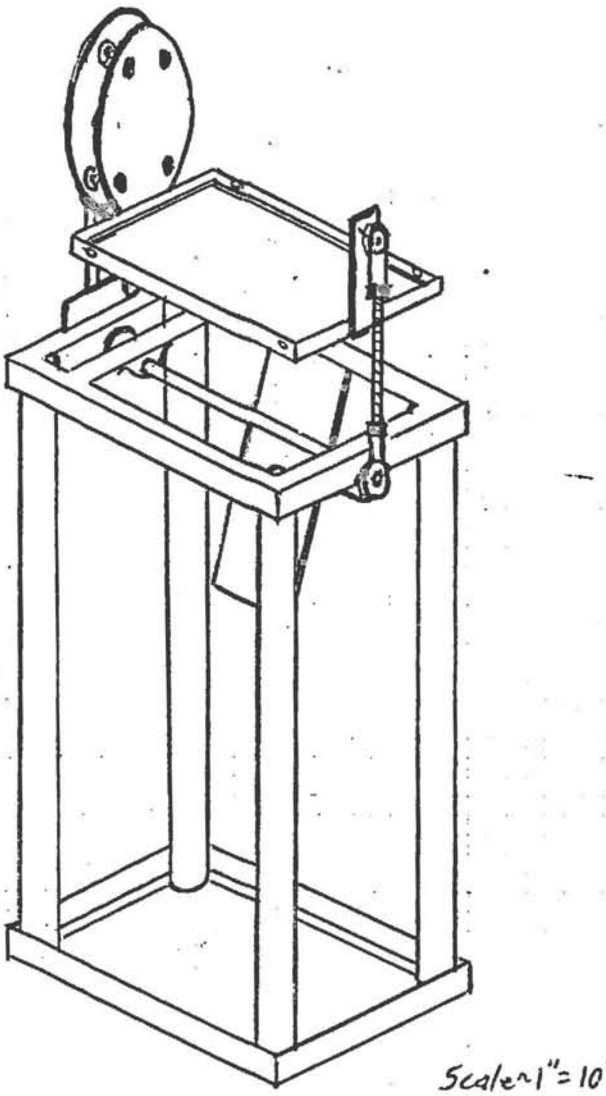
APPENDIX B

SHAKER DESIGN DRAWING

AND PARTS LIST

W.R.W. PYCNOMETER SHAKER

FOR USE WITH 11¾" diameter
Asphalt Pycnometer
COLORADO PROCEDURE #42-C



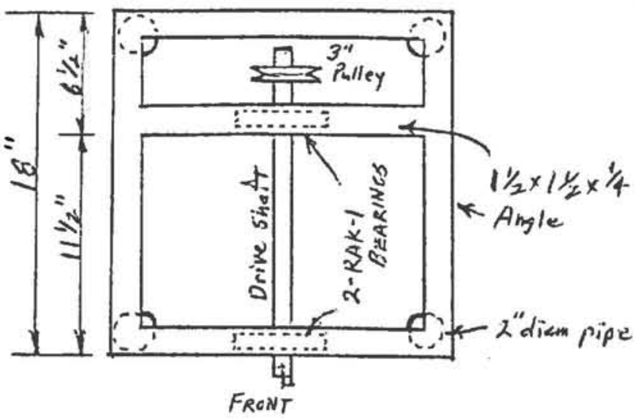
Scale~1" = 10"

MOTOR & BELT NOT SHOWN

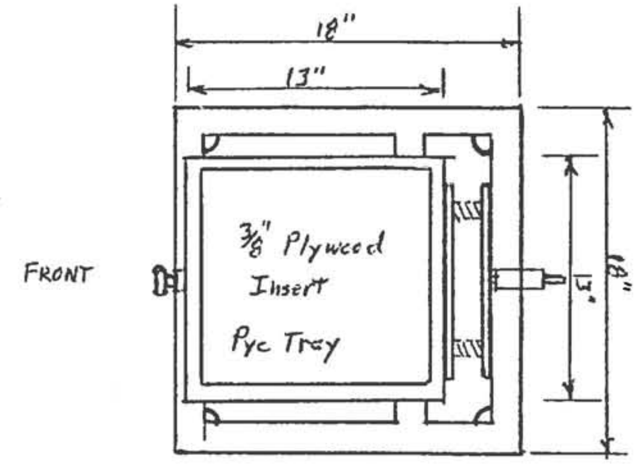
Prototype employed an 1140 rpm motor, a 4" pulley on the upper 1" diam. driveshaft and a 3" pulley on the motor to obtain a driveshaft speed of 850± r.p.m.

MATERIALS LIST

- 1 - 1½" x 1½" x 15" Angle — Top Frame Cross piece
- 8 - 1½" x 1½" x 18" Angle — Top & Bottom Frame
- 4 - 2" diam x 30" Pipe ⅛" wall — Legs
- 1 - 4" x 12" x ½" Plate — MOTOR Mount
- 1 - 1" diameter x 18½" Round stock — Drive Shaft
- 1 - 4" x 1½" x ¼" Plate — Reinforcing Plate
- 1 - 1" x 1" Box STEEL 10" long — Support Arm
- 1 - ⅝" diameter x 3½" long Round Stock — Dowel
- 1 - ¾" O.D., ⅝" ID x 2" long Tube — Dowel Sleeve
- 2 - 10" diameter x ¼" thick plate — Spring Supports
- 8 - 1½" ID Rings - ≈¼" high cut from 1½" I.D. pipe — Spring Retainers
- 4 ≈1½" O.D. x 2" long Springs (Valve Springs) — Springs
- 4 - 1" x 1" x 3/16" Angle (1½ x 1½ material may be substituted) — Pyc Tray Frame
- 1 - 5¼ x 2 x ⅜ plate — Tray / Bearing Connection
- 4 - 3" x ⅜" Machine Nuts + Bolts — Spring Support Plate
- 1 - 1" x 3½" Machine Bolt — Drive Shaft Connection
- 1 - 2" x ⅝" Machine Bolt — Tray/Bearing Connection
- 2 - Fafnir Bearings # RAK 1 — Drive Shaft Support
- 1 - Fafnir Bearing # REP 8M10 — Upper Tray Bearing
- 1 - Spherco Bearing # TR 10 — lower Tray Bearing
- 1 - ⅝" diam x ≈5½"-6" long Threaded Stock Cut to needed length — Upper/Lower Bearing Connector
- Sufficient nuts and bolts to make up Connections and support pillow Bearings
- 2 - ¾" O.D., ⅝" ID x 2" Tube — hinge - Motor Mount
- 1 - ¾" O.D., ⅝" ID x 4" Tube — hinge - Motor Mount
- 1 - ⅝" diam - 9" long Round Stock - hinge pin
- 1 - ⅜" x 12½" x 12½" plywood - Pyc. Tray Base.

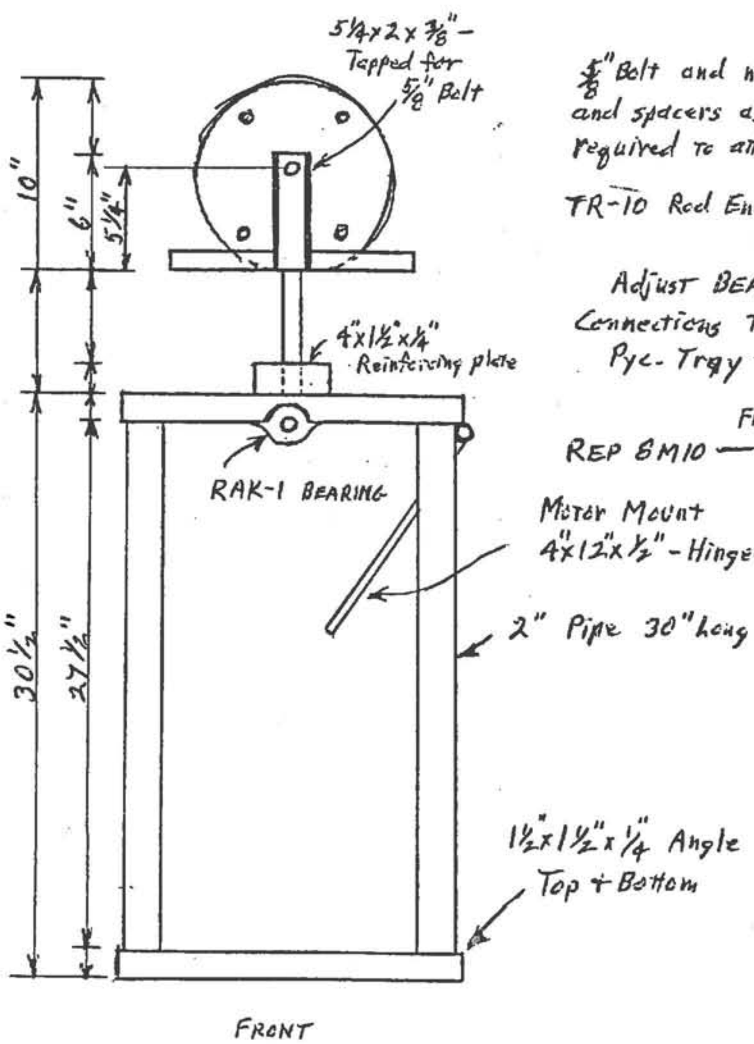


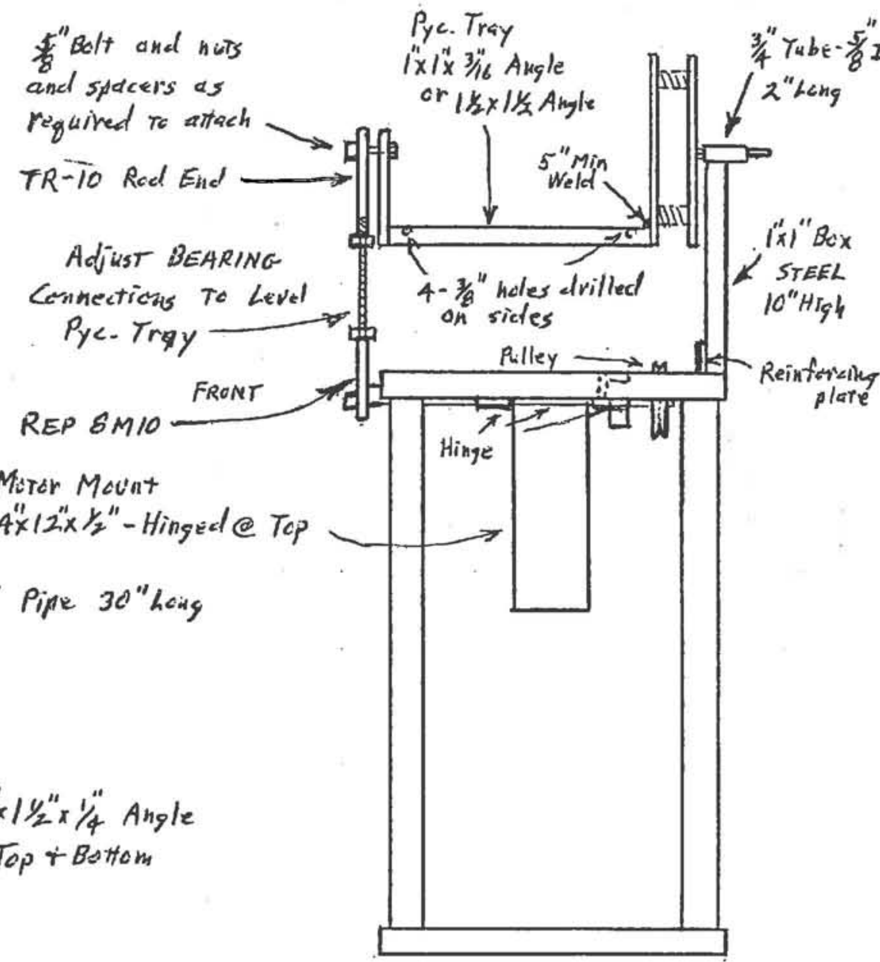
Top View - Pyc Tray removed for clarity



Top View - w/ Pyc Tray

Pyc-Tray Plywood insert to have ¼" deep - 11¾" diam centered routed out portion for Pyc-





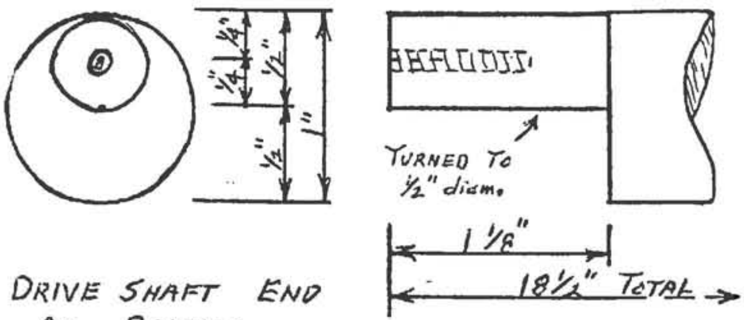
Pyc. Tray MUST BE ROTATABLE

RECOMMENDED DRIVE SHAFT ROTATION - 850 RPM

Scale ~ 1" = 10"

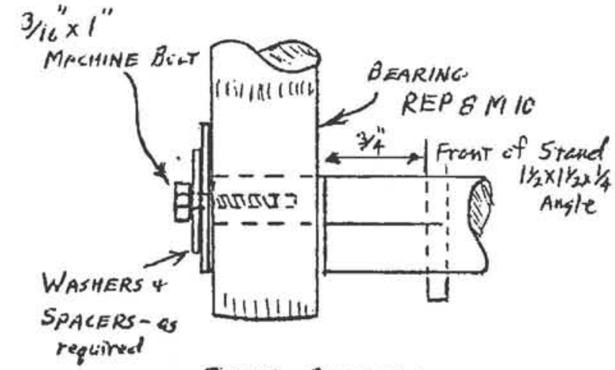
Pyc. Tray Outside Dimensions 13" x 13"

4-holes - ⅜" diam. to be drilled in Pyc-Tray Sides - near corners for Rubber Tie-down Straps for Pycnometer hold downs.



Drive Shaft End at Bearing

Tapped for 3/16" dia. Machine Bolt ≈ 3/4" deep



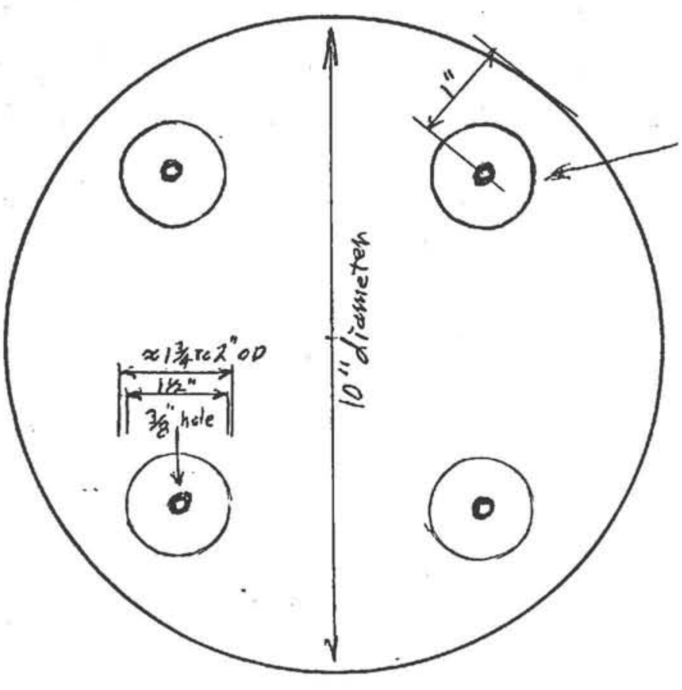
Drive Shaft & Bearing Connection

Shaft Rotation to be Counter Clockwise (↶) By This View.

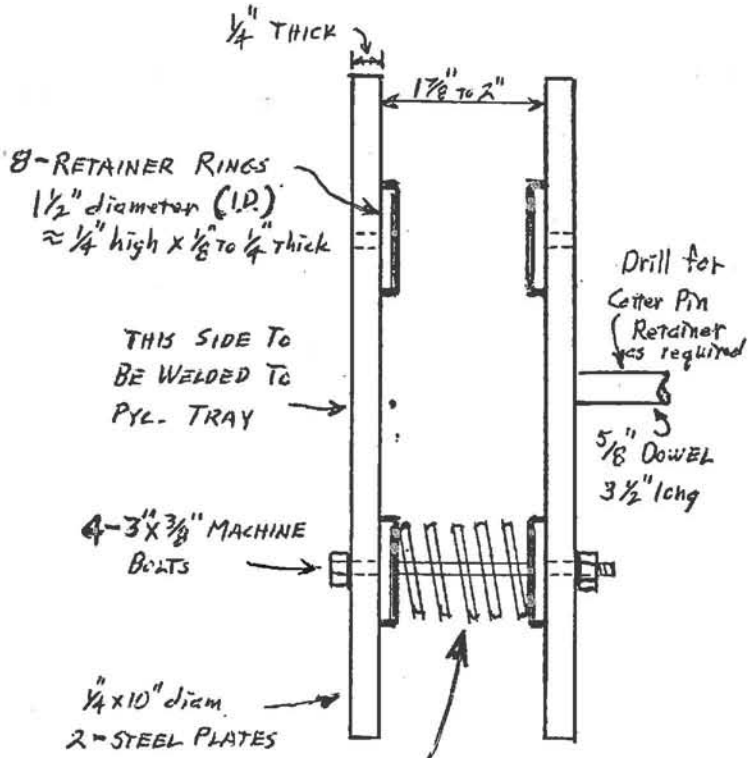
Scale ~ 1" = 2"

Drive Shaft End Details

Scale ~ 1" = 1"



Drill Four (4) 3/8" Holes – Equally Spaced Around the Plates – 1" From Plate Edge – Center the Spring Retainer Rings on the 3/8" holes and weld in place



4 – Valve Springs ~ ≈ 2" Long

Springs should not be welded in place.

Spring / Plate Details

No Scale