# MEASURING ROAD RUNNING COURSES

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PROVERBS 20 #10 - "Divers weights, and divers measures, both of them are alike an abomination to the Lord."

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NOTE: The figures at the end of some sentences, for example (6), refers to the number of the source of the information, which can be identified by checking the reference list on pages 39-41.

# I N T R O D U C T I 0 N

Man measures speed, strength, and endurance performances for purposes of comparison. These measurements form the basis for establishing new goals in the field of athletics.

The real prizes or rewards for most long distance runners are the times they record at various distances. To make recorded times meaningful, road racing courses should be accurately measured. A.L. Monteverde, who raced from 1881-1936 states that "road courses are in measurement most inaccurate. There is no financial profit derived by such runs and economy rules." Corrective action is urgently needed in the USA. It is unnecessary and unfair to the competitors to call a 9 mile course or a 11 mile course a 10 mile race, as is often done. It would be better to say "approximately 10 miles," if the distance is not known exactly. However, it is possible to obtain exact, meaningful measurements of course lengths.

Road race sponsors can do a great service for the sport by accurately measuring the course of their races. A course need not always be exactly a round numbered distance such as 5, 10, or 30 miles. Except for the marathon (26 miles 385 yards) and specific championship races, road racing courses may be of any convenient distance. The promoter need not change his established course but the course should be accurately measured and the distance called what it is. It has been argued that road race courses have their own personalities, terrain, weather, scenery, and records, which cannot be duplicated elsewhere. Many of these variables also exist in reference to 440 yard tracks, and even in the case of swimming pools, competitors often label a given pool as either fast or slow. Man insists on measuring time (easy to get accurately) and distance (difficult to get accurately) for comparison purposes. Athletes and fans assume that the correct distance of the race course is the advertised distance and they relate timed results not only with past performances on the course but to times made on other courses of the same distance. Another factor was pointed out by John Sterner in 1949 when he stated that, "I think the cause of so many American (marathon) runners doing so well here and then falling down when they run overseas can be traced to the fact that almost all road runs here are run over short courses."

This indictment is still true, because the automobile odometer is the most commonly used method of measuring road racing courses in the USA. This method almost invariably leads to short courses.

Observations of numerous racing results suggests that if the course is accurately measured, the course record will fall within a relatively narrow time range. A time very far off of this time range immediately signals that some unusual factor is operating, for instance: unusual weather; short course; etc. Whenever a super-fast time is recorded, the course should be re-checked immediately to confirm the distance. Runners all over the world may be interested in the exactness of the distance and a re-measurement and announcement of the results will settle the question of the distance. Two examples illustrate the point. In 1952, England’s Jim Peters raced the "Poly" Marathon in a fantastic 2:20:42.2, raising questions as to the accuracy of the course. Several re-checks found the course to be over the regulation 26 miles 385 yards. The "two-twenty" marathon was here to stay. In 1959, C. Kennedy, Michigan State University, raced over the Inter-collegiate (ICAAAA) 5 mile cross-country-course in Van Cortlandt Park, Bronx, N.Y. in 23:51.8. Two teams of student surveyors checked the course and found it short by 490 and 497 yards respectively. The course was lengthened 490 yards.

The problem of course lengths is not new. Arthur Newton has told of his experiences in 1923 and later when he was attempting to break world records in the ultra-long distances in Africa. Measurement methods have not changed much since that time. American officials have lagged behind most countries in getting reasonably accurate road courses, settling for the inaccurate results of quick surveys by automobile odometers.

## ROAD RUNNING COURSES

Increasing vehicular traffic adds to the difficulty of selecting road courses. The future will probably see road races largely confined to suburbs, small towns and parklands, and races held in the early hours to avoid traffic.

Upon establishing a race, try to select a permanent course and avoid repeating all the work on a new course each year. A set course allows runners to compare their efforts with previous performances and with runners of other eras on the same course (41).

Land areas can be divided into three classes: 1) Level: features few or no hills or valleys; 2) Rolling: features hilly country; 3) Mountainous country. These areas may merge into each other or they may be found on one route (37). Generally, the race sponsor must use local land areas. In some instances, he will have a choice of setting up an easy (flat) course, or a fast (slightly rolling) course, or a hard (hilly) course. The good, well-trained runner can race over any course.

The gradient (grade) of a slope is the rise or fall in a given distance along the level. Gradients are indicated by fractions, e.g. 1/30 means a slope rises 1 foot in a horizontal distance of 30 ft.

There are several types of courses: a CIRCULAR course (e.g. Yonkers Marathon); a POINT-TO-POINT course (e.g. Boston Marathon); a LOOP course of several laps (e.g. Culver City Marathon); an OUT AND HOME or a SWITCH BACK course (e.g. Atlantic City Marathon); and a FIGURE-EIGHT or other figure course (e.g. Van Cortlandt Park cross-country course, or the Hamilton, Ontario, Firestone 25 kilo run).

If possible, locate the start, finish, dressing room, presentation of prizes, etc. in one area, thus simplifying organization of the race. A course of several laps ("Out and Back" or "Circles") is ideal because it is easier to handle traffic and to man refreshment stations, and it permits spectators to view the race several times. Also, in extreme heat or cold, runners can stop in more favorable spots if necessary, and in those cases where a runner is in trouble from heat exhaustion, he can be watched and pulled out of the race before it is too late. A "figure-eight" or "clover-leaf" shaped course permits the start and finish in the center with the above advantages (41,53).

Other Considerations:

1) Prepare a map of the course and display it in the dressing room or distribute copies of it, possibly reproducing it on the entry form.
2) Measure the course accurately so that it is the advertised length. If possible, mark the course with mile or kilometer points so that they can be seen. This will make it unnecessary for competitors to depend on the inaccurate information often supplied by onlookers.
3) Avoid main roads unless certain of sufficient police protection against traffic.
4) Place easily seen direction signs along the course to guide the runners. Avoid confusing the runners at intersections. Arrows and painted lines (which are not to be crossed, thus heading the runner into the right path) may be used in some instances. These aids are supplemented by having an adequate number of guides on the course.
5) The start and finish, or both, of a road race may be on a track making it easy to add distance to complete the advertised distance.
6) To break up the monotony of the course, use terrain which includes hills and flat areas. However, the land areas in which the event is to be held will determine the nature of the course.
7) At the marathon distance, some thought should be given to standardization of courses to make comparison of times more meaningful. Cerutty recommends that marathons be run on lap courses of 1 to 5 miles, accurately measured; that the course be as level as possible; and that the course be on dirt or grass. He suggests that while classical courses like Boston should stand, all Championship courses should be standardized as outlined above. Thoughtful, business like planning would lead to more support for long distance running.
8) A course "watch dog" is needed. This could be a two man team who would note changes in the course and see that corrective action is taken to keep the course at the advertised length.
9) Care and attention are essential whatever the method used to measure a course. The measuring team should get a lot of practice, and re-checking courses is a good method.
10) Road Runners Club Associations and other bodies interested in long distance running should combine efforts to persuade race promoters to measure courses accurately.

## METHODS THAT HAVE BEEN USED TO MEASURE ROAD RACING COURSES

A variety of methods have been used to measure road courses. These include: steel tape, automobile odometer, measuring wheel, surveyor's chain, etc. Many of the methods which have been used do not permit the accuracy needed for road courses.

Some comments on methods that have been used:

J. Barry (New Jersey): "The only way to measure a course is as I've done by hand. A 100 ft. tape. It's hard and takes quite long to do. But it can be done."

N. Farrell (Canada): "Measure course forward and backward with about five new cars. They should first be checked on a measured course. Go to the Police Department. They have a measured mile strip and also a gadget to check speedometer accuracy."

NOTE: This commonly used method of measurement is too inaccurate for checking road racing courses.

A. L. Monteverde (California): "Road race courses should be surveyed by competent engineers."

J. Jewell: "The recognized method of measuring road races in this country (England) for running and walking races is by surveyor's wheel although in actual fact the promoters of road races use a number of methods."

B. Prentice (Australia): "I find the wheel more accurate than steel tape and chalk marks and much quicker, and to my mind is about as close as you can get." (He used a specially constructed measuring wheel.)

## RECOMMENDED METHODS OF MEASURING ROAD RACE COURSES

Ideally promoters of road and cross-country races would have all courses surveyed by competent engineers. This is not always possible or practical. The use of a calibrated bicycle, as used by the Road Time Trials Council in England, is highly recommended for measuring road courses (21). The steel tape is the third choice if experienced personnel are available. The surveyor's wheel is another acceptable method. Large scale maps may be used with satisfactory results. The automobile, as ordinarily used, is not suitable for measuring road courses.

The Amateur Athletic Union of the U. S. Official Track & Field Handbook, in referring to national championship long distance runs, states that "all courses shall be properly marked and measured by measuring wheel or tape." This rule has seldom been observed in the past.

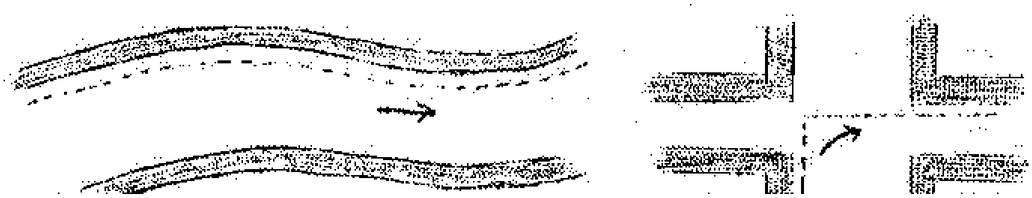
## WHERE TO MEASURE A ROAD COURSE

There is a need for uniformity in measuring the path of a road course. Some comments on methods that have been used:

R. Campbell (Massachusetts): "Cut all turns - here again we know that due to traffic one may not be able to cut the same turns each year. It might be well to measure the course by keeping in the middle of the road."

S. Hamilton: "In Finland, the Government Surveying Office measures the distance running courses in the middle of the road, and the sports people take their verdict as 'it'."

S. Takenaka (Japan): "Measure road course on the roadway off one meter from the boundary of the sidewalk (left side)."



J. Jewell: "Roads are measured here according to IAAF rules, one meter from the curb on the left hand side of the road in Great Britain. There is of course a certain ambiguity in measuring right hand turns, etc. but this is the guiding principle."

P. W. Cerutty (Australia): The course is measured accurately where the runners will run as is done in track. This cancels out all variations and gives some uniformity for comparison between different countries and efforts."

B. Prentice (Australia): “Usually measure one meter from the kerb, elsewhere as near as possible to where the athletes will run.”

RECOMMENDATIONS ON WHERE TO MEASURE ROAD RACING COURSES

The International Amateur Athletic Federation (IAAF) rule requires that road courses be measured one meter (3 ft. 3 inches) from the left hand curb of the road in the running direction. In those countries where traffic rolls on the right side of the road the course may be measured on the right side in the running direction. In the interest of uniformity this principle should be applied whenever possible. Otherwise, measure where the runners will run, that is, on the runner's path.

On some roads it will be impossible to measure the course one meter from the curb due to parked vehicles. Here one might measure a distance of a car width plus one meter from the curb, and on extended stretches free of parked cars revert to the one meter from the curb rule.

Jewell reports that measurements made by the Road Time Trials Council method are done on the path followed by the runners when no obstructions exist, with a general regard to the IAAF rule. The runner runs according to the dictates of the circumstances, without running extra distance, and with regard to the traffic and considerations of sportsmanship. Investigation suggests that little distance is saved by the runner taking short cuts, such as crossing to the other side of the road (21).

ACCURACY

The measurement of road courses is a form of surveying. It is not possible to measure any distance with complete accuracy. The precision of measurement will depend on the care with which it is made and the instrument used. Regardless of the method used, a certain percentage of error exists due to mistakes (eliminated by checking the work); to systematic errors; and to accidental errors. Aim to keep the errors to a minimum through careful work and by rechecking the measurements (12,45).

One approach is to check the course measurement by an alternate method. For instance, if the course is measured by a surveyor's wheel, it may be checked by use of a large scale map. Keep dates and records of all measurements including intermediate distances which would be useful in case of road alterations (21).

Jewell quoted from the Road Times Trial Council report on Course Measuring, the following: "No reliance should be placed on information regarding distances supplied by Local Authorities or by the Police, as such information is often inaccurate and the methods of measurement employed are very rarely to the high standard of accuracy required by the RTTC. Neither should any reliance be placed on milestones as they are generally very inaccurate, and where road alterations have taken place since they were installed, are often many furlongs out of place (21)."

If a distance is measured very accurately several times by the same method, it is usually found that the results vary slightly from one another. The true measure of the distance is taken to be the mean of the different results obtained, that is, the sum of these results divided by their number. This is called the mean value or most probable value. "By the law of probabilities, the chances are even that the error made in using the mean value does not exceed a certain quantity, called its probable error (6)."

Jewell states that Standard Times, including Road Runners Club Standards, are given to the nearest minute, and so "the distance of a road course should at least be correct so as to ensure that the athlete's time to the nearest minute is the correct time to the minute at the particular distance in question, i.e., if his marathon time is 2:20, the error on the course distance should not be such that his real marathon time is not less than 2:19:30 or more than 2:20:30. This means that <u>the error on the course should be less than the distance the athlete covers in half a minute.</u> A much higher degree of accuracy can easily be attained... The greatest error which is permissible for courses of difference distances are.

| | |
|---|---|
| 10-miles (Record 47:47) | 184 yards |
| 20-miles (1:42) | 173 yards |
| Marathon (2:15) | 171 yards |
| London to Brighton. (5:26) | 143 yards |

Thus the error of measurement at the marathon distance should not exceed 6.5 yards per mile, or error of 0.37% (21).

MEASURE CONVERSIONS

The yard and the meter are legal measuring standards in the USA. Both systems are used in national championships. The meter, 39.37 inches or 3.28 feet, is often called the "world yard" and it is about 10% more than the yard. The world mile is from the Latin mille, meaning 1000. Since a double pace is 5 feet, one thousand paces is approximately 5000 feet, or about one mile. The American mile is 0.1818 inch longer than the British mile (28).

| The YARD System | | The METRIC System | |
|---|---|---|---|
| 1 inch = | 0.0833 foot | 1 meter = | 39.37 inches |
| | 0.00278 yard | | 3.281 feet |
| | 2.54 centimeters | | 1.094 yards |
| | 0.0254 meter | | 0.001 kilometer |
| 1 foot = | 12 inches | 1 kilometer = | 3280.83 feet |
| | 0.333 yard | | 1000 meters |
| | 0.3048 meter | | 1093.61 yards |
| | 0.00019 mile | | 0.6214 mile |
| 1 yard = | 36 inches | 1 mile = | 63,360 inches |
| | 3 feet | | 5280 feet |
| | 0.000568 mile | | 1760 yards |
| | 0.9144 meter | | 1.609 kilometer |

STANDARD DISTANCE

An accurately measured standard distance on a road, preferably straight, is needed to check the accuracy of measuring instruments. Select a level and not heavily traveled road. The distance should be one mile or more. If necessary the distance may be less than one mile. Use a team of at least two men and a calibrated 100 ft. steel tape to measure the distance. The tape is held on the ground under 10 pounds of pull or tension (checked by a spring scale). Mark off reference points on the side of the road with paint, or nails or pegs, etc. Check the measurement several times. Some cities maintain a standard of length with which tapes may be compared. If possible the standard distance should be cross-checked by other personnel (20,21,26).

Jewell points out that "Secondary Standard Distances" may be set up from the standard distance using the calibrated bicycle method. To do this, record the number of revolutions of the front wheel by a counter as the cycle is ridden over the standard distance. The cycle may then be ridden to or transported to the site of the second standard distance. The number of revolutions between the start and finish of the distance measured is then used to determine the length of the new standard distance by working it out by simple proportion. The same is done when measuring a road course.

Example: If 1700 revolutions = 1 mile, and
If the course measures 1300 revolutions, then

$\frac{1700 \text{ revs}}{1 \text{ mile}} = \frac{1300 \text{ revs}}{x \text{ miles}}$, then 1700x = 1300

$x = \frac{1300}{1700} =$ 0.7647 mile

1760 yards (1 mile)
0.7647 mile (multiply by)
1345.87 yards
length of course

Note: carry the mileage factor to the 4th decimal place (58)

COMMONLY USED METHODS OF MEASURING ROAD RACE COURSES

Responsibility for measurement of the road race course falls on the promoter of the race. Generally the method of measurement selected depends upon the precision required, the cost, and other considerations (11). A description and evaluation of commonly used methods of measuring road courses will follow. They will be classified into three groups: recommended, questionable, and not recommended.

RECOMMENDED METHODS OF MEASURING ROAD RACE COURSES

I. SURVEYING

Surveying is the art of making relatively large, precise measurements of distance with a maximum of accuracy and with a minimum expenditure of time and labor (23). It is concerned with determining the relative location of points on or near the surface of the earth. The principles of plane surveying involve a working knowledge of geometry, trigonometry, physics, astronomy, and theory of probability. Surveying is done by professional surveyors (11,12).

EQUIPMENT - Surveyors employ the transit and level and other tools. Surveying instruments are self-calibrating and they can be adjusted to eliminate any errors that tests disclose (8,23).

METHOD - Surveying involves making measurements of four types of dimensions: horizontal lengths, vertical lengths, horizontal angles, and vertical angles. Horizontal lengths are usually measured with steel tapes, usually graduated in hundredths of a foot. The degree of accuracy of a horizontal measurement is usually expressed as a ratio of the error of the total distance measured. Ordinary measurement with a steel tape gives an accuracy of about 1 part in 3000 (1/3000) (23).

ADVANTAGES - Accuracy is assured.

DISADVANTAGES - Employing a surveyor is expensive. The price may be prohibitive in most cases except on small loop courses. Inquire locally about prices.
PRECAUTIONS - Select a reliable, interested surveyor who possesses sound judgement (23).

RELIABILITY - The surveyor will provide the most reliable results possible. He will obtain the accuracy needed for road race courses without difficulty. The random errors which occur tend to be either plus or minus and in most cases they cancel each other out by the laws of chance.

## II. TAPE MEASUREMENTS OR "CHAINING"

Direct measurement by steel tape is the most commonly used reliable method of determining distances between two points. This method is called taping or "chaining." Links of iron or steel (chains) are seldom used anymore but the term "chaining" is still used to designate measuring with a chain or with tape (6).

EQUIPMENT - 1. Use a calibrated steel tape 100 feet in length. If necessary, a tape 150 feet long may be used. A tape may have a handle at each end or it may have leather thongs or string or hooks at the ends. Check whether the graduation marks begin on a line on the tape or on the handle assembly.

A 100 feet Engineer's or Surveyor's steel tape will cost about $30.00 and up. Band chains or chain tapes, used for route surveys, cost about $20.00 plus about $12.00 for a reel. A general purpose 100 feet steel tape costs about $11.00 (59).

2. Spring balance or spring balance handle, attached to the forward end of the tape to indicate the amount of pull applied to the tape. Its use will improve taping accuracy to 1:3000. It costs about $12.00, reading to 30 lbs. Certain tapes are calibrated to measure correctly when under a certain tension. The tension is held while the measurement is made. This gadget may also be used to counteract the effect of sag when making measurements with an unsupported tape (59). Often in practice, the experienced surveyor will use judgement rather than the spring scale.

3. Recording and marking materials.

a) 4H pencil and paper or field notebook for notes, etc.

b) A red pencil to mark the taped distances on the road surface.

c) Keel or lumber crayon to mark a circle around the red penciled mark or an arrow pointing to the red mark to make it easier for the rear tapeman to find the red mark (45). The number of tape lengths may be written on the pavement with keel or chalk.

d) A hammer and cold chisel to make a permanent mark, for example, a +, at specific checkpoints. On some surfaces nails may be driven into the roadway to make a permanent mark. Optional: paint a small circle around the permanent mark.

e) Plastic flagging tape may be used to temporarily identify landmarks or checkpoint stations. This tape is put on the road surface and may be written on with pencil or ball point pen. A 300 foot roll of this tape costs about $1.00.

4. Miscellaneous tools:

a) If part or all of the course is on dirt or grass, use chaining arrows to mark tape increments. A set of 10 steel arrows costs about $5.00. The lead tapeman starts off with the 10 arrows. He places an arrow at each tape length of increment until he has used them up. The rear tapeman collects the arrows. This serves as a check on errors: the collection of 10 arrows indicates 10 tape lengths.

b) A tape thermometer to measure the tape temperature if accuracy greater than 1:3000 is sought (23). Minimal cost is about $4.50. The thermometer is fastened directly to the tape. Many surveyors do not use temperature corrections except for special jobs. Temperature may introduce an error up to 1:5000 (23).

c) A plumb-bob is a brass body suspended from a cord. It is used to facilitate measurements with the tape supported at the ends only. Obtain two bobs. Costs range from about $4.50 to $8.50 for the 1 to 1.5 lb. sized bob generally used. It is difficult for amateurs to use plumb-bobs because the tape and bob tend to move during measuring.

NOTE: Minimal equipment for tape measuring a course: 100 ft. steel tape, spring balance, and recording and marking materials. These tools can give the degree of accuracy required for measuring road courses. Use a folding rule or a meter stick for tape alignment.

CARE OF TAPE - Tapes are easily damaged or broken and require care in handling and storage. Before using the tape, examine it for kinks. When the tape is being stored, clean, dry, and grease it lightly with vaseline. Kits for repairing tape are available from the manufacturer for about $34.00.

To unroll tape, one man holds the case and the other man walks away with the free end. The back man signals the lead man to stop before the end is reached, but he is also set to give ground to avoid a sudden jerk on the tape.

To roll up the tape, the tape is laid out straight on the ground and the man doing the winding walks toward the free end. Tapes are usually wound up in cases or on rods. They require constant cleaning and oiling to prevent rust. Never put a tape away wet.

To avoid damaging the tape:

1. Steel tapes will stand a tension of 80 or more pounds but they will break easily with misuse.
2. When the tape is lying on the ground, keep it extended so that slack is eliminated thus preventing the formation of loops which lead to kinks and breaks.
3. For measurements of less than a full tape length, the tape should be kept on the reel. Reel out as much as you need and reel it in as soon as possible.

4. If the tape is on the ground and is to be moved, drag it from one end only. If the tape is to be raised off the ground, the tapemen (those handling the tape) should lift it simultaneously and keep it in tension. Otherwise the rear tapeman should not touch the tape while it is being moved.
5. Do not let vehicles run over the tape. If this is unavoidable, the tapemen should hold the tape flat and tightly pressed against the road surface (8,23).

CALIBRATE TAPE - For precision work, the tape should be compared with a tape certified by the National Bureau of Standards. This comparison with a standardized tape or length should be repeated frequently because tapes are easily damaged, leading to incorrect length which leads to errors. Many cities have standards of length which may be used to check a tape.

The National Bureau of Standards, Washington, D. C., will check a steel tape against the official standard, employing any specific pull, temperature and conditions of support to the tape. A fee of $21.00 plus mailing costs for the tape are charged (11,59).

Systematic errors due to incorrect tape length are eliminated by standardizing the tape and getting a correction per tape length if it is not the exact length.

Systematic errors due to sag, temperature, pull, slope, and habits of placing the mark either inside or outside the true distance, can be allowed for and corrected. Accidental errors are always possible, even with conscientious work, and under normal circumstances the minor errors should balance themselves. Guard against making accidental errors systematic (2).

ERRORS in chaining are of two classes:
1) Errors due to faulty chaining and to natural conditions:
a) Imperfect alignment of tape: tape out of line or not horizontal. If one end of a 100 ft. tape is 1.4 feet higher or lower than the other end the tape will be 0.01 foot shorter. The same displacement to the right or left of the true position will make the tape 0.01 foot shorter (22).
b) Variations in tension of the tape: having pull insufficient to compensate for the effects of sag and of the wind.
c) Imperfections of observing, including careless plumbing.
d) Incorrect length of tape. An old, worn tape will stretch more under tension than a new one. Often, old tapes have been broken and repaired several times and this can lead to errors in length.
e) Variations in temperature.
f) Sag in tape (6,11,22).
2) Errors in reading or recording measurements:
a) Using the wrong zero point on the tape.
b) Reading the wrong foot mark.
c) Reading the tape upside down, thus mistaking some figure such as a 6 for a 9 or vice versa.
d) Transposing figures in recording, for example: 71.23 instead of 72.13.
e) The recorder misunderstanding the reading called by the chainman.

f) Mistakes in counting the full tape lengths (6).

SPECIFIC FORMULI are used to make measurement corrections such as slope correction, temperature correction, tension correction, and correction for sag of the tape, such as when measuring over rocky ground for example (22). These corrections are generally not used in road course types of measurements.
SAG and PULL - If the ground is rough and the tape cannot be supported evenly along its entire length, it is necessary to apply a correction for the sag of the tape.

The formula for sag is as follows:

Let L = Length of the tape in feet.
P = Pull applied in pounds
W = Weight of tape between supports in pounds

$$\text{Sag correction in feet} = \frac{L \times W^2}{24 \times P^2}$$

WHERE TO MEASURE - Use the international rule: measure the course 3 feet 3 inches (one meter) from the curb in the running direction. Otherwise measure where the runners will run as is done in track.

METHOD - Form a "taping field party." A minimum of two men are needed to measure a course. If possible, organize a team of up to seven or eight men with one or two cars. Place one man at each end of the tape.

Duties of the taping field party may be divided as follows:

1. Chief - He should have some experience in surveying. He closely supervises the measuring. He might act as rear tapeman and serve to guide the lead man in getting proper alignment. He might also keep records unless another man is along to record.

2. Lead Tapeman - He carries a red pencil and keel to mark tape increments. He uses a meter stick or a folding rule for alignment.

3. Recorder - He marks and describes in notes each 0.5 mile and mile. It is important to have records of intermediate and check point distances for future reference (39). Field notes should be clear and complete giving numerical data, explanatory notes, and sketches made approximately to scale in a notebook (11).

4. Tension man - If a spring scale is used. Otherwise the lead tapeman handles the spring balance (scale).

5. Assistant - Directs traffic, and assists otherwise (22,39).

TAPING or Chaining - <u>There are two methods of taping</u>: Surface Chaining and Catenary Chaining.

1. SURFACE CHAINING with a steel tape. Use a 100 foot tape. Tapes longer than 100 feet are generally not used for measurements along the ground. If possible, a spring balance registering pulls up to 15-30 lbs. is attached to the forward end of the tape. Check to locate the end of the tape and the zero mark.

Lay the tape flat on the road surface. The rear tapeman holds his end of the tape on the line (mark). The rear tapeman directs the lead tapeman for proper alignment. Where it is possible to apply the international rule of measuring one meter from the curb, the lead tapeman uses either a meter stick or a folding rule to obtain the proper alignment. The lead tapeman applies 10 lbs. of tension (pull). To make certain that the tension is not taken up by friction, the lead tapeman might increase the tension to about 20 lbs. and then reduce the pull to 10 lbs. The lead tapeman then marks the tape increment by any of several methods as follows:

> On pavement, mark the spot with a red pencil and circle this with yellow keel or lumber crayon. An alternative is to use either medical tape or special plastic tape on the road surface and make the mark on it with a red pencil or a ball point pen.
>
> On grass or dirt use chaining arrows or pins to mark the spot. Another possibility is to put a tack or nail into the ground.

After marking the tape length the lead tapemen walks forward dragging the tape. The rear tapeman notifies him when to stop. Another possibility is for the rear tapeman to walk forward and take the tape from the lead tapeman and continue on for the next tape length.

In measuring around turns or curves, measure in increments of 5 or 10 feet instead of full tape lengths (45).

If at the end of the measurement, a less than full tape length increment is needed, the head tapeman should do one of three things to avoid getting the tape messed up:

1. Carry the end of the tape beyond the end point, lay it on the ground and walk back.
2. Reel in the tape the necessary amount
3. Take in the tape by forming figure-of-eight loops hanging from his hand. This takes practice to master (23).

Working <u>tape tension</u> - Steel tapes graduated in feet require tensions when supported on a flat surface as follows: a 100 ft. long tape requires a tension of approximately 10 lbs. A tape over 100 ft. long requires a tension of approximately 20 lbs. The tension required for a tape supported throughout on a flat surface is about the same for any part of the tape as for the full length (59).

The coefficient of expansion of steel tapes is 0.00000645 per degree Fahrenheit. Thus a 100 ft. tape will elongate 0.00774 inch for each degree F of tape temperature rise above 68 degrees F (59).
The Keuffel & Esser Co., Hoboken, New Jersey, recommends tapes with a thermometer scale as a means of obtaining additional accuracy and uniformity in measuring. This thermometer scale is graduated to correspond to the contraction and expansion of the tape, according to the F thermometer for tapes graduated in feet. It takes the place of the terminal mark of the tape, and the terminal point lies at that mark of the thermometer scale which corresponds to the prevailing tape temperature reading at the time of taking the measurements (59).

2. CATENARY CHAINING with steel tape. This is a more accurate method than surface chaining but it is more difficult to execute. If the ground is rough or the surface is not cleared of obstacles, this method is recommended. The tape is supported at the two ends by the tapemen. It is necessary to compensate for sag.

The tapeman should face the tape

1. Each tapeman supports the tape above waist height, the same height above the ground. One man applies tension through a spring balance.

2. The rear tapeman holds a plumb-bob with which he makes certain that the mark on the tape is vertically above the mark on the ground.

When a tape is used suspended from the ground, a plumb-bob is used to transfer the ends of the measurement to the ground. The bob is suspended from a cord which hangs over the tape. The plumb-bob is held so that its point is close to the ground, but not touching it; when the tape is taut and properly aligned, the plumb-bob cord is released by the tapeman and the mark is placed where the point of the bob strikes the ground (6). It may be necessary to dampen the swing of the plumb-bob by moving the tape up and down slightly, tapping the point of the bob on the mark (23). As the bob rests on its point, the tape is released and a mark is made at the point made by the bob.

3. The lead tapeman hold his end steady against the tension with one hand. When the rear tapeman signals that everything is ready, the lead tapeman transfers the forward mark on the tape to the ground by means of a plumb-bob held in the other hand (8).

4. The lead tapeman uses either a meter stick or a hardwood folding rule to get the proper alignment of the tape from the curb: 1 meter.

Working tape tension - The tension required for a steel tape when supported at the ends only depends upon the unsupported length and the cross-sectional area of the tape. A 100 ft. steel tape at 68F and supported at the ends only requires the following tensions, depending on the type of tape:

| | | | |
|---|---|---|---|
| 3/8 inch Medium | = 20 lbs. | 5/16 inch Heavy | = 24 lbs. |
| 1/8 inch Chain | = 19 lbs. | 5/16 inch Extra Heavy | = 31 lbs. |
| 1/4 inch Chain | = 27 lbs. | 5/16 inch Chain | = 31 lbs. |

Recommendations: For measuring a road course, sufficient accuracy is obtained by using the method of surface chaining. Tape temperature correction may be ignored except in extreme weather conditions since the error will fall within allowable limits.

ADVANTAGES - Trained operators can obtain a high degree of measurement with the use of tapes.

DISADVANTAGES - Direct measurement by steel tape is not the most practical means of measuring road courses due to traffic and to the effort and time demanded. However, on short loop courses and courses in park lands these factors are less important. The big disadvantage is the time required, at best about 2 miles an hour (45).

PRECAUTIONS
1. Heat affects the length of the tape.
2. Avoid measuring on windy days.
3. Tapes are liable to become inaccurate with use. Tapes are not provided with any means of adjustment so that any inaccuracy found to exist in its length must be noted and added to or deducted from the measurements taken.
4. Steel tapes are only of correct length when they are at a certain tension and temperature, usually 10-15 pounds and 68F respectively. The tension and temperature at which the tape is of standard length is often stamped on the handle or on a metal tag attached to the handle (22,30).

RELIABILITY - A steel surveyor's tape is one of the most accurate methods of measurement but it requires skilled use, especially in measuring around turns (45). With a calibrated tape, you can expect an accuracy of about 1/1000 or better. If a spring balance is used to maintain the appropriate constant tension and if temperature and slope corrections are carefully observed, an accuracy of between 1/1000 and 1/10,000 may be obtained (8,12). The highest accuracy is obtained on flat ground, cleared of obstacles. Precision may be as high as 1/30,000 (11). Sterner states that a distance measured by tape should not be considered accurate unless at least one member of the party has had some surveying experience (45).

III. CYCLISTS' METHOD (Used by the Road Time Trials Council, England)

The following method of road course measurement described by Jewell is that method developed by racing cyclists in England who compete in Road Time Trials. Due to the fact that times are compared on different courses all over England, a given distance in one area must be the same distance on another course in another section of the country. The cyclist's time trial courses are designed so that there is no advantage in terrain by a given area, and generally, out and home courses are used. This is the same thing that will have to be done in the sport of road racing to make the comparison of road running results, especially the marathon, meaningful on an international basis (21).

EQUIPMENT

1. A bicycle with good tires and tubes.
2. The bicycle is fitted with a revolution counter. "The revolution counter resembles a normal cyclometer and has a similar method of operation: a striker fitted to the cycle wheel engages a 'star' wheel on the counter attached to the frame or forks. Several types of counters have been tried but only one has proved satisfactory and that is the 5 star type made by Veeder Root Inc., Hartford 2, Connecticut." The counter is a small star wheel revolution counter with gib mounting B-100725.

Order Series B-100725 Star Wheel Revolution Counter, from Veeder-Root, Inc., Hartford 2, Conn. Delivery 4-5 weeks.

The Veeder Root Star Wheel Revolution Counter is sold at $5.30 each in quantities of 1 to 9. However, for orders of less than 10 of these non-standard counters, a lot processing charge of $17.50 is applied to the order. Quantities of 10 to 24 are sold at $4.51 each. Contact the Road Runners Club, USA, national president or the chairman of the Road Runners Club Standards Committee for information on obtaining a counter at cost minus the lot processing charge.
3. Steel tape to make short measurements on the course in special situations, for example to locate a check point mark, or if the course suddenly and briefly changes to rough terrain, etc.
4. Recording materials: pencil and notebook.
5. Road marking materials to establish check point marks. These might include a hammer and cold chisel and paint, and nails in instances where surface permits their use.

METHOD - "The basic method consists of riding a bicycle fitted with a counter registering the number of revolutions of one of the wheels, over the route to be measured. Immediately before, during or immediately after the measuring, the bicycle is ridden over a known and very accurately measured 'standard distance' and, from the readings obtained, the number of the revolutions of the wheel per mile is calculated. This becomes a 'constant' for that particular measuring occasion, and this constant is used to calculate actual distances from the revolution counter readings (21)."

The counter registers the actual number of revolutions of the cycle wheel and does not, as in the case of the cyclometer, convert readings into miles and fractions of a mile.

The biggest task in this method is the measurement of the standard distance. An accurately measured STANDARD DISTANCE must be established.

To establish a standard course or distance, use the procedures described in the section on tape measuring. (see pages 11-17)

Other possibilities include: 1) Hiring a surveyor to measure a one mile (or less) standard distance; 2) Asking a local surveyor to volunteer his services for this purpose.
Once a standard is set, use it to calibrate a measuring wheel, bicycle, etc.

The start and end of the standard distance should be well defined so that anyone else can recognize and ride over the exact path of the standard course. The exact terminal points can coincide with some permanent and accurately definable points, and where necessary, reference to precise alignment should be made, together with some suitable permanent marking.

A straight road is ideal for the standard distance but not essential. The curb of the road should be permanent and clearly defined so that the measurement can be taken at some fixed distance (for example 3 feet) from it. The measurement is always taken on the same side of the road unless it is dead straight.

In riding over the standard distance to obtain the constant, the measurer should ride in exactly the same manner and in the same position as he will use during the actual course measuring. He should follow the exact line of measurement of the standard distance. Obtain a fresh constant on each separate measuring occasion.

Fractions of a revolution may be calculated from the spokes. The spoke carrying the striker may be marked near the hub and the number of spokes past or short of the counter are counted at the end of the measurement. If the wheel has 32 spokes and the striker is 2 spokes past the counter it is considered 2/32nd revolution or "two spokes." The standard distance should be ridden over at least twice.

Before measuring, the revolution counter should be checked to see that it is fitted and working satisfactorily. The tire of the measuring wheel should be sound and free of suspicion of leakage. "It should be inflated hard but not 'board' hard (21)." At the starting line, set the bicycle wheel in the zero position, that is with the striker on the point of leaving the star wheel.

The cyclists convert the revolution counter readings to actual distances by the aid of conversion tables but simple arithmetic may be used, as follows: multiply the number of revolutions taken to cover the course (or lap) by the standard distance (in yards) and divide by the average number of revolutions taken to cover the standard distance. The result is in yards, but this can easily be converted into miles and yards. See page 37.

An example of a measurement follows: A 1100 yard standard distance stretch was measured twice and required the following number of revolutions of the bicycle wheel:

496 23/32 and 496 24/32 revolutions.

The number of revolutions needed to cover the road circuit to be measured was 5254 11/32 revolutions.

The bicycle was again ridden over the 1100 yards measured standard distance and 496 25/32 revolutions were required.

Mean constant 496 24/32, equals 496.75 revs.

Hence: length of lap is $\dfrac{\text{1100 yards x 5254.34 revs (measured course)}}{\text{496.75 revs (standard distance)}}$

= 11635.2 yards = 6 miles 1075 yards.

OTHER CONSIDERATIONS - If possible measure the course on cool, dull days since a hot sun expands the tire and alters the constant. Do not walk any part of the course. It is not advisable to measure more than 50 miles on a single occasion. A suitable riding speed is 10-12 miles per hour. Take notes of the course measurement including intermediate readings "so that the whole course need not be remeasured if road alterations are made (21)."

Promoters of road races may be able to contact a cycling club for the purpose of having courses measured or checked, after obtaining the special Veeder-Root Star Wheel Revolution Counter.

ADVANTAGES - The Road Time Trials Council Method is a simple, accurate, and rapid method of measuring road running courses. It can be used at a speed five times as fast as a surveyor's wheel.

DISADVANTAGES - None.

PRECAUTIONS - Obtain a fresh constant on each separate measuring occasion. Do not take a short cut in calibrating the bicycle on a standard distance by marking the bicycle wheel with chalk and measuring a few revolutions on the road with a tape.

RELIABILITY - The Cyclists' Method has an accuracy of +/- 10 yards in 25 miles. The precision of greater than 1 yard per mile is more than accurate for road race course measurements. A course measured a number of times by this method will reveal similar results (21).

NOTE: The Cyclists abandoned measuring wheels 30 years ago in favor of the method described above, because extreme accuracy is required. The RTTC also points out that Surveyor's Chains are generally not accurate enough for measuring road courses.

## IV: SURVEYOR'S MEASURING WHEEL

The surveyor's measuring wheel is a rubber tired wheel used for giving a rough, rapid measurement of distance on smooth surfaces. The Official AAU Track & Field Handbook states that courses in championship runs shall be measured by measuring wheel or with tape. The surveyor's wheel is not a precision instrument and it is not simple to obtain the accuracy needed for road racing courses. These wheels tend to over value measured distances, that is to produce "short courses." With careful technique the needed accuracy can be obtained with the surveyor's measuring wheel.

EQUIPMENT - Ideally, the wheel should be wide enough to prevent wobble, and the unit should be of sufficient size to give the wheel stability.

1) The following portable measuring wheels are available:

a) "WHEEL-N-MEASURE METER"
Records in feet, up to 99,999 ft. Wheel circumference 36 inches. Veeder Root five digit meter can be easily reset to zero. Price $49.50
Order from - B. G. Reilly Co., P. O. Box 1849, St. Petersburg, Florida; or from the same company at P. O. Box 231, No. Scituate, Rhode Island.
Also from the same company: "TRACKMASTER MEASURING WHEEL," which records up to 99,999 ft. Price $55.00

b) "TRUMETER ROAD MEASURER"
Weight 7 lbs. Rubber tire. Several different calibrations available. Calibrated in either yards or feet and fractions thereof, up to 99,999 ft. Metric system calibrations available. Price $85.00.
Order from TRUMETER CO., 38 W. 32nd St., New York 1, New York.

c) "THE WOLVERINE"
Records in feet. Rubber tire. Wheel circumference 36 inches. Order from: Wolverine Sports Supply, 3666 South State St., Ann Arbor, Michigan. Price $49.95.

d) "THE ROLATAPE"
Model 400: Spoke measuring wheel. Price $59.50
Model 415: Wheel 15 inches in diameter. Neoprene tire. Registers to 100,000 feet, almost 19 miles. Graduated in inches and tenths of a foot. Price $62.50.
Order from: Rolatape Inc., Santa Monica, California; or from: Keuffel & Esser Co., 15 Park Row, N. Y. 38, N. Y.; or from source mentioned in #c above.

2) In addition to the measuring wheel, a steel tape is needed for short measurements in special situations, including the pin-pointing of checkpoint stations.

3) Marking materials: A red pencil and keel to make marks on the road surface. Hammer and chisel to make "cross-cuts," + on the street or sidewalk. Painting a small circle around the cross is optional. Take one or more measurements, by tape, from the "cross-cut" to nearby permanent landmarks. Record in notebook and use the information to relocate the mark.

METHOD - The first step is to calibrate the wheel by walking it over a previously measured standard distance, e. g. a one mile section along a straight road if possible, to check its accuracy (45). Jewell states that "it appears to be useless to test the accuracy of a surveying wheel on a track partly owing to the nature of the surface and also owing to the difficulty in following any prescribed path accurately round the track (21)."

Apply the average error found in the trials over the measured standard distance to correct the actual wheel readings. This correction will give better measurement results.

To measure the course, set the counter at zero, or start from the existing reading on the counter, depending on the features of the wheel. The axle is placed over the starting line. If the wheel has a striker, position it so that it has just left the counter so that when the counter first registers, the wheel will have made one revolution. As you walk, keep the same distance from the curb, walking straight and at a uniform speed.

The wheel should be pushed one meter (3 ft. 3 inches) from the curb in the direction of running. A second choice is to measure along the path to be taken by the runners as is done in track.

Walk over the course at about 2 miles an hour, pushing the wheel by its handle. If the operator has a partner to record results, it is possible to move a little faster. Better results are obtained by walking the wheel slowly and steadily. Take the counter reading when the axle of the wheel reaches the finish line.

No corrections are needed for air temperature variations (21). There is always some slippage due to insufficient friction in operating wheels, the amount depending on the surface being measured. Even with careful operation, wheels slip and light wheels bounce creating inherent errors in this method of measurement. Wheels tend to over-estimate road courses.

The measuring wheel may also be used in conjunction with other methods for comparative measurements, such as when choosing an alternative road or for altering the start or finish of a course.

To set up a correction table for use in the field: Example - The surveyor's wheel is pushed over an accurately measured mile, 5280 feet. The wheel in this case records 5292 feet. To complete the calibration, divide the recorded reading into the actual distance: 5280/5292 = 0.9977 which becomes the correction factor. To find the actual footage, multiply the wheel reading by the correction factor, 0.9977 (58).

ADVANTAGES - The surveyor's wheel is one practical method of measuring road racing courses since it can be used by an inexperienced person with a little practice (45).

DISADVANTAGES - The surveyor's measuring wheel has its limitations: it is not intended for precise surveying. The road must be smooth to use a measuring wheel.

PRECAUTIONS - The light weight, narrow measuring wheels available now, lead to inaccurate measurements in that they tend to over estimate distances. Errors tend to increase as the speed of walking increases much over 2 miles per hour (21). Running with the wheel or towing it by car is not recommended.

RELIABILITY - The surveyor's measuring wheel may give measurements correct to 5 yards per mile when pushed slowly and operated carefully (21). This degree of accuracy is just sufficient for road course measurements. However, unless operated properly, these wheels produce too large an error for acceptance in road racing.

NOTE: Measuring wheels have been called by such names as Hodometers, Odometers, Perambulators, and Waywisers. Each is a wheel of known circumference, either connected by a train of gears to a counting mechanism or the counter is activated by a striker on the wheel. The distance indicated by a wheel is somewhat greater than the true horizontal distance, but this method of measurement is sufficiently precise for some purposes. Errors are plus and it is not possible to underestimate distances when using these wheels (11,12,21).

## V. MAP MEASUREMENT

There are several types of maps depicting land areas. The map should contain: statement of scale, title, and the north point. The surveyor takes measurements and observations of land and makes a map to scale. Large scale maps may be used to measure a road course.

EQUIPMENT - Obtain a large scale map of the specific area in which the course is to be laid out. A scale of 1" to 150' is ideal. Smaller scaled maps may be used. The scale of a map is a statement of the relation between a distance measured on the map and the corresponding distance on the ground, for example: 1" = 200' means 1" on the map represents 200' on the ground. Another example: $\frac{1}{63{,}360}$ means that 1 inch on the map represents 63,360 inches, one mile, on the ground (12,53).

The U. S. Department of the Interior Geological Survey has made series of topographic maps to cover the U. S. The unit of survey is a quadrangle bounded by parallels of latitude and meridians of longitude. Many areas are published at different scales. Whenever this occurs, the map order should include the map series designation, such as 7.5 minute series (published at the scale of either 1:24,000 or 1 inch = 2000 ft., or 1 inch = 0.5 mile when published at 1:31,680), or 15 minute series (scale of 1:62,500, or 1 inch = approximately 1 mile), or 30 minute series (scale of 1:125,000, or 1 inch = approximately 2 miles). A few special maps are published at other scales as listed in the individual state indexes under special headings. Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangle maps that have been published.

For information and a free folder describing topographic maps and symbols, write to the Map Information Office, Geological Survey, Washington 25, D. C. Order maps from the same source. In many cities, map stores can supply these maps.

The extent of map coverage is shown on index maps, on which the mapped areas are outlined in black. Write for index to maps of your state. From the index, order the maps you need by the names printed in black and by series designation. Obtain the 7.5 minute quadrangles which at 1 inch = 2000 ft. is a larger scale map than the other series. The quadrangle may not contain the whole area that you want so more than one map may be needed. The standard topographic quadrangle map is about $0.50 per copy.

Many libraries have map reference facilities. Use a ruler, or string in checking library maps.

It is usually possible to view or to purchase large scale maps of local streets or roads. Possible sources include: the city or local Bureau of Engineering; or Department of Highways; or the Water and Sewage Dept.; etc. Usually one such department will have the responsibility of surveying streets in each city. Streets must be surveyed before they are built. Theoretically every paved road and street in the USA has been accurately surveyed and mapped to scale (44).

A screw type adjustable divider is used to scale or measure from the map. A second choice is to measure with a ruler, preferably a metric straight edge ruler. A ruler would be needed in any case to measure right angled turns if a divider is used to measure the course. These supplies may be purchased in stationery stores or stores selling art or drafting supplies.

METHOD - The route for the road racing course is measured with an adjustable divider which is used on the scaled map. A ruler may also be used to measure the distance after checking the scale of the map (53). To operate the divider: set the instrument for a ground distance of 20 to 30 feet (if using a large scale map). If a small scaled map is used, set the divider for 1/10 mile or other convenient distance.

The selected increment is pricked slightly into the map paper for each length. To begin, set the divider legs on the course path with one leg on the starting (or finish) line. Press both legs into the paper. To move forward, pivot on the front leg and turn the back leg forward and puncture the paper with it. Repeat, turning to left and right alternately. Travel in a straight line along the route.

It is easier to hold the instrument with the thumb and index finger. Avoid holding it by the stem (leg). Mark every mile point or mark certain intersections or check points in pencil as the measurement proceeds. This will give a check on the increments.

One should be able to hit intersections or check points repeatedly on re-checks of the course. Inspect pricks in the paper made by the points of the divider. Recheck the course several times each way.

Errors tend to occur going around a turn, in that you will get a shorter measured distance than the actual distance, tending to produce a long course. This error can be minimized with careful scaling of the path. When measuring right angle turns, it is advisable to use a ruler to permit the use of small increments of measurement until the turn is completed.

Ideally one man should do the mapping, including re-checking his work, and then someone else should check the distance. The course should finally be checked by travelling over the path by any convenient means with the map at hand. An up to date map is no guarantee that there have not been temporary or permanent changes in the road.

After using the divider awhile, recheck its calibration against the scale of the map.

ADVANTAGES - Large scale maps provide the simplest and fastest method available for measuring a road course. A map allows the race organizer to try several different routes on paper. Maps may be used to check measurements by other methods, for example a surveyor's wheel, and as a check against gross accidental errors (21).

DISADVANTAGES - The measurement of a winding course is not easy and requires the largest scaled map available.

PRECAUTIONS - Obtain an accurate large scale map for good results.

RELIABILITY - Map measurements tend to be made with a greater degree of refinement in city surveying than for land of less value. Scaling a distance from a large scale map gives sufficient exactitude for road racing courses if done properly (45). The small errors which occur are not cumulative. Errors using a divider will tend to make a course long rather than short.

Jewell found agreement between map distances and the wheeled distances (Calibrated Cycle Method) very good; the difference between the two averaged 4 yards per mile, and was the same independent of the scale of the map. The accuracy attained depends on the ability to follow the turns of the road by the map measurer (e. g. divider) or other device. Jewell prefers a thin piece of cord to a map measurer (divider). The cord is laid on the map and manipulated around the bends with the fingers. He claims that measurements can be repeated to 0.05 inch (21).

## MEASURING METHODS RECOMMENDED WITH RESERVATIONS

It is strongly suggested that the race promoter select one, or more of the recommended methods of measuring to check his course distance. The methods include: surveying by a professional surveyor, tape measurement, calibrated cycle method, surveyor's measuring wheel, and map measurement. However, if the promoter finds it impossible to use one of these methods, there are three additional possibilities which can be used to measure with sufficient precision for road race courses if certain procedures are followed. These methods are: the "fifth wheel," home made measuring wheel, and the automobile odometer.

### I. FIFTH WHEEL

The "fifth wheel" is a small device, usually a special wheel, which is towed behind a car. It may be used to measure either the distance or the speed traveled by an automobile.
EQUIPMENT - Most "fifth wheels" are owned and used by automotive manufacturers and are not likely to be available for the average race promoter. However, the equipment is commercially available. The Tracktest Equipment Co. 27110 Scenic, Franklin, Michigan, sells a "fifth wheel," Model 5101 Trackmeter, for $760.00 (46,49).

The instrument consists of a balanced, rubber tired pneumatic wheel, approximately bicycle size, mounted on a frame. The device may have either a mechanical or an electrical counter connected at the hub. It records in tenths, hundredths, and thousandths of a mile (26). It usually connects to an electric speedometer/odometer inside the automobile and records both speed and miles covered.

METHOD - The "fifth wheel" is clamped to the bumper of an automobile so that it can be towed. The wheel must be calibrated against an accurately measured mile. The air pressure in the tire should be maintained at a steady value as indicated by a calibrated tire pressure gauge (26).

Place the "fifth wheel" so that the center of the hub is directly over the starting point. The counter is then zeroed. Drive at a speed that allows the wheel to be kept firmly on the road surface.

Re-calibrate the "fifth wheel" before each use to include the proper correction factor.

ADVANTAGES - The "fifth wheel" gives rapid measurement of distance.

DISADVANTAGES - The "fifth wheel" is expensive. However, the race promoter might investigate the possibility of borrowing one.

PRECAUTIONS - Calibrate the "fifth wheel" against a measured mile. Drive the automobile with care during all measurements (46).

RELIABILITY - The "fifth wheel" is not a precision instrument and it possess the inherent defects of the surveyor's wheel. The accuracy is better than 99% with careful operation. Skilled use of the device will give the precision needed for the measurement of a road running course (20,46,49).

## II. HOME MADE MEASURING WHEEL

It is possible to make a good, reliable measuring wheel but it is suggested that the advice of an engineer be sought before constructing the wheel (39).

EQUIPMENT - Bob Prentice of Australia constructed a wheel which was accurate and which was adopted for official use in the state of Victoria. In fact he measured the course which was later surveyed and used for the Melbourne Olympic Marathon. He has walked the wheel over most of the road running courses in his state.

Prentice described the construction of his home made wheel as follows:
1) Use an ordinary 28" bicycle wheel. Remove the tire and tube.
2) Construct a steel rim and attach it to the bicycle wheel. The rim is made of steel 1/8" or 3/16" thick and 2" or 2 1/2" wide, for stability. This strip of steel is welded into a circle with an outer circumference of 8 feet 1/4 inch. The extra 1/4 inch balances almost exactly the amount of wobble when the wheel is used. The rim is riveted to the wheel. The rivets are counter sunk. Bolts may be substituted for the rivets. Sleeves are attached to make the rim taut.
3) Construct metal forks and a handle and attach this assembly to the wheel. Use steel 1" or 1 1/4" wide and 3' to 3'6" long. The two pieces of metal are secured by sleeves. The handle is one foot long and is attached to the end of the fork. This aids in the balance of the wheel.
4) A revolution counter with a striker pin is attached to the wheel. Prentice's wheel makes 660 turns (revolutions) to the mile.

Check and recheck the wheel over an accurately taped measured mile, walking at a steady 4 miles an hour, or preferably less, with the wheel in front of the operator.

It is advisable to make tables of the number of revolutions of the wheel needed for one kilometer and for one mile and for fractions of and multiples of these distances (51).

Some athletic clubs have made their own measuring wheels using a bicycle wheel and revolution counter. The front fork of the bicycle may serve as the handle (38). This type of measuring machine would not produce the reliability displayed by the wheel described by Prentice.

METHOD - Calibrate the wheel by walking it over an accurately measured mile. Take the wheel to the course to be measured. Walk over the course with the wheel, concentrating on walking on a straight path. Measure one meter (3 feet 3 inches) from the curb or on the path the runners will take. One man can cover up to 3 miles an hour. If he has another man to record results, he can cover up to 4 miles an hour on a good road with a wheel of the type made by Prentice.

ADVANTAGES - It is possible to get results of sufficient precision if the wheel is well constructed, stable, calibrated correctly, and operated with care.

DISADVANTAGES - Great care is needed in the construction of a measuring wheel. Otherwise the error in measurement will be too large for acceptance in road running course measurements.

PRECAUTIONS - The wheel must have much more weight and stability than commercial wheels to make it worth constructing. If the steel rim is used, the welder should understand the situation fully.

RELIABILITY - Prentice checked his wheel numerous times and it was never more than 6 to 12 inches off when walked over his accurately measured mile. He feels that his wheel is more accurate for road course measurement than a steel tape and chalk marks and much quicker, and that it is about as accurate as you can get. Generally the reliability of a homemade wheel should be proved - by calibration and comparison with other methods - before acceptance for measuring road courses; otherwise they are not recommended. Accuracy is the goal (5,20).

VARIATIONS - An odometer is an instrument for measuring distances traveled by a vehicle. Odometers may be attached to wheels of various vehicles. These vehicles are not recommended except for very rough measurements, after calibration on a standard mile course. Road course measurement needs are better met with previously described methods such as tape measurements or the calibrated cyclist’s method.

## III. AUTOMOBILE ODOMETER

The automobile is the most commonly used method of surveying roads for road races in North America. It is not a recommended method because the distance indicated by the mileage recorder or the odometer is somewhat greater than the true distance covered (12). Most American automobile manufacturers have apparently deliberately set both speedometers and odometers optimistically on their automobiles to satisfy the urge for speed and economy in gasoline mileage. This may explain the tendency for imported automobiles to have more accurate odometers than American made automobiles (45,49). "The Automobile Manufacturers Association admits that odometers are set to overregister from 1% to 5%. On top of that tire wear gradually ups a car’s odometer reading by another 1% from what it was when the tires were new (55)." This means that <u>if you take a measurement directly from the odometer you can generally count on a short road racing course</u>. Occasionally an automobile measurement may lead to a long course due to under-registration by the odometer.

If one must use an automobile to get a rough measurement of a road course, steps should be taken to get the most out of the instrument.

EQUIPMENT - An automobile equipped with an odometer that has been calibrated.

An air-pressure gage and a tire-tread depth gage may also be used.

Materials for record keeping.
If possible, the driver should use an assistant who should also be in the automobile when it is calibrated over a standard distance.

DISCUSSION - The terms odometer and speedometer are commonly used interchangeably. The speedometer is a device which measures speed. The odometer, a part of the "speedometer" assembly, is an instrument which measures distance traveled by the vehicle.

The mileage recorder of an ordinary automobile odometer registers distances to 0.1 mile. Special survey odometers are available reading to 0.01 or 0.001 mile. Both types of recorders must be checked on a reliable certified testing machine. The ordinary odometer may be checked by a reliable speedometer shop, especially if their business consists of fleet automobile and trucking concerns (49).

Another solution is to operate the automobile for 10 miles between mileage markers on a turn-pike and note the mileage recorded on the odometer in order to determine if it is accurately recording distance. If it is not, then divide 10 miles by the miles recorded on the odometer to arrive at a correction factor. Multiplying this correction factor by an odometer reading will give you reasonably accurate mileage. As an example, if, when you travel a 10 mile turnpike distance your odometer registers 10.4 miles, then divide 10 by 10.4 which equals 0.9615. This figure can be used as a correction factor. Then if you measure a course by your automobile odometer and it records 21.3 miles, you multiply 21.3 by 0.9615 to get a reasonably accurate course distance of 20.48 miles. Any change in tire diameter or tire pressure can change the correction factor. Obtain a new correction factor before each measurement (47).

Use the same arithmetic whether the odometer is over-registering or under-registering. To determine the correction factor, divide the odometer reading, obtained by driving over the calibration course, into the accurately measured distance of the calibration course. The calibration course should not be less than 5 miles long. Use 10 miles or more if possible. This may be done on an accurately measured loop of +/- 1 mile (58).

Example: Drive the automobile over the accurately measured 5 mile calibration course. The odometer reading is 5.3 miles. Then the,

$$\text{True Distance} = \text{Odometer reading (on course being measured)} \times \frac{5}{5.3} \text{ (the correction factor in this case)}$$

$$\text{True Distance} = \text{Odometer Reading} \times 0.9433 \text{ (correction factor)}$$

If the road race course measured 12.8 miles on the odometer, then

True Distance = 12.8 x 0.9433
True Distance = 12.0742 miles
1760 yards (1 mile) x 0.0742 = 130.59
True Course Distance = 12 miles 130 yards

Errors are caused by changes in tire inflation, increased tire pressure caused by temperature increase due to tire friction on the highway, wheel bounce, differential action and other factors (46).

The National Bureau of Standards investigated the use of odometers recently. Their report of the effects of variables in using an automobile for road measurement follow:

Wet pavements: Slippage of the rear wheels on wet pavement causes larger positive errors than dry road conditions.
Vehicle speed: As the speed is increased from 30 miles per hour to 60 mph the odometer reading tends to decrease on the average by a factor of 0.55% of the distance traveled. High speed driving usually causes a pressure build up in the tires.
Vehicle tire pressure: If tires are inflated above the recommended pressure, the odometer reading is decreased (26).

Make the odometer check immediately before the course is to be measured because even slight variations in air pressure of the tires will make a big difference. For example, if loss of air in the tire permitted a loss of diameter of a half inch (settling of hub 1/4 inch), this would make a difference in circumference of the Diameter multiplied by 3.1416 or in this case 0.5 x 3.1416 = 1.57 inches per revolution of the wheel, and that would make quite a difference in a marathon course. A new tire would have a greater circumference than a well worn tread. Treads of different manufacturers would differ in thickness of treads, etc (42).

Measure a mile (+/-) loop calibration course with a calibrated 100 ft. steel tape. Hold the tape under 10 lbs. of tension. Select a little used road as the calibration course. A loop calibration course permits the automobile to be driven a number of laps adding up to 5 or more miles. An alternative is to use official local measure standards. The police department, or some other local agency will have a measured mile strip and also a gadget to check odometer accuracy (14). Tire companies may also have an accurately measured mile. To be of use in calibrating an odometer, these short measured courses should be loop courses. Turnpikes and throughways have accurately measured miles along their routes, sometimes at mile intervals along the shoulders in both directions for the entire length of the road. The accuracy of the mileage markers is within 1% (56).

METHOD - To get the most out of the automobile as an instrument for measuring road courses, use precise and exacting procedures.

Vehicle odometer accuracy can be evaluated precisely by several methods including the "fifth wheel" device, the measured road course, and the simulated road tests using a special device for odometer testing. The first two methods give the highest degree of precision (26).

The following steps may be taken:

1. Have the odometer in the automobile calibrated for accuracy by an accredited "speedometer" specialist (36). Consumers Union of the US Inc., reports that it is a simple matter to adjust odometers to register nearly accurately (55).

2. Use an air pressure gage to measure the air pressure in the tires. Adjust the pressure to the level recommended by the tire manufacturer (26).

3. Standardize the mileage recorder by driving the automobile over an accurately measured distance such as a tape measured loop of a mile or more, or over a 10 mile stretch of turnpike (12). Check the automobile several times. This is done immediately before the course is to be measured. When driving over the accurately measured course to check the odometer, have the same passenger(s) and load in the automobile that you will have during the course measurement.

4. Immediately after step 3, go to the starting line, or finish line of the course to begin the measurement.

a) It is easy to make sighting errors when looking at the odometer. Put a small piece of tape or other marker above the odometer to facilitate sighting at the same place and in the same way each time (19).

b) Either set the odometer at zero or jack the automobile up and turn the rear wheel until the odometer is at an even digit or until the indicator is where you want it (1).

c) If possible, have one man drive the car and read the instruments, and have a second man make sketches of the course and keep notes and records on the course measurement.

d) Drive over the course when traffic is light. Drive over the path the runners will take.

e) The road should be dry at the time of measurement.

f) McSweeney recommends driving at a speed of 10 to 20 miles per hour. The National Bureau of Standards study indicated that speeds over 30 miles per hour tended to decrease the odometer error. It is suggested that the measurement speed be the same as that used on the calibration course.

5. Finally, correct the distance recorded on the odometer - unless the McSweeney method is being used. The procedure for correction has been described under above Discussion.

ADVANTAGES - The automobile odometer provides a fast method of getting a rough measurement of a road course.

DISADVANTAGES - Consumers Union of U. S. Inc., engineers have found that automobile odometers almost always over-register. The average odometer error is 3.5 per cent (55). A study in 1963 by the National Bureau of Standards, Washington, D. C. indicated that the average odometer in automobiles provides an over-registration error of more than 3 per cent under standard test conditions (26). New automobiles are equally faulty in this respect. Direct reading from the odometer is unacceptable for road course measurement unless the McSweeney calibrated method is used (21).

PRECAUTIONS - If an automobile must be used to measure a road racing course, have the odometer calibrated for accuracy by an accredited "speedometer" specialist. Then follow the procedure described above under Method.

RELIABILITY - Automobiles, motorcycles, scooter bikes, etc. are not reliable means of measuring distances (39). The odometer tends to provide greater over-registration errors for city roads than for highway conditions (26). Tests indicate that wet pavements and added vehicle loads tend to increase the odometer error, while increased vehicle speed and increased tire pressures tend to decrease the error (26). Errors in measurement range from about 3% to 10%, or more, in excess of the actual distance covered by the automobile. The road running course will be "short" by the error of the odometer. This points out the fallacy in measuring a course with several different automobiles and taking the average as the course distance (20,45).
Conclusion: Taking a reading directly from the automobile odometer is not acceptable for measurement of road running courses. However, by calibrating the automobile and paying attention to correct procedures, it is possible to get acceptable measurement results. The automobile odometer has such a bad reputation that any measurements made with it will remain suspect and the race organizer would be wise to spend his energy measuring his course with one of the methods listed under acceptable measuring methods such as "chaining" (tape measure), or the "calibrated cycle method."

THE McSWEENEY METHOD

The McSweeney method takes the ordinary odometer (mileage indicator) and produces suitable results in road course measurements by calibrating the automobile. Jewell has described McSweeney's method as follows: Calibrate the car mileage recorder on a standard mile before use. This is similar to the method used by the Road Times Trials Council (calibrated cycle method) which uses an accurate calibration of a pneumatic tire before use in measuring distance.

McSweeney adjusts the tire pressure so that readings of the mileage recorder are correct; whereas with the cyclists' method it is only necessary to blow up the tire hard and to determine the number of revolutions covered in a mile. The rest is simple arithmetic.

McSweeney recommends a maximum speed of 20 miles per hour on a smooth road, otherwise 10 mph. To calibrate the automobile, drive to the measured mile. Check the pressure in the tires to see that they are always the same as on previous occasions. McSweeney has an accurately measured one mile loop. He drives around the one mile loop 5 times and if the mileage recorder comes up to the mile exactly at the same spot every time around, he goes to the course to be measured and does the job. If necessary he adjusts the tire pressure until he gets a correct recording. When he changes tires, he experiments again until he gets the one mile lap accurate again on the mileage recorder (21).

## MEASURING METHODS WHICH HAVE BEEN USED BUT WHICH ARE UNRELIABLE

The following methods are NOT RECOMMENDED.

### I. BICYCLE AND CYCLOMETER

A bicycle may be used for very rough road surveying.

EQUIPMENT - A bicycle and a cyclometer made for the wheel diameter of the bicycle. The diameter of the wheel must be at the specific value for the set revolutions of the cyclometer to record an accurate mile. The usual cyclometer, designed for a 28" wheel, requires 720 revolutions of the bicycle wheel to record one mile. It is attached to the axle of the front wheel of the bicycle. A cyclometer may be obtained which registers distance in miles and tenths of a mile. The air pressure in the tires and the weight of the rider play roles in the effective diameter of the wheel (29,40).

METHOD - First determine the error of the bicycle by riding it over an accurately measured strip of road of at least one mile, preferably more, and comparing its true mileage with that registered on the cyclometer. The tires should be pumped up hard (18,29). Calibrate the bicycle before each measuring job.

After riding over the calibration course, a correction factor can be determined by dividing the cyclometer reading into the standard distance. Then after riding over the course to be measured:

$$\text{True Distance} = \text{Cyclometer Reading} \times \frac{\text{Standard Distance}}{\text{Standard Distance Reading}} \qquad (58)$$

ADVANTAGES - The bicycle is a rapid, rough means of measuring distances.

DISADVANTAGES - The ordinary cyclometer registers only eighths or tenths of a mile and is too coarse for road course surveying.

PRECAUTIONS - The road surface is a factor in the accuracy of the results. The cyclometer is designed for a 28" wheel. However, with a rider on board the tire deflation may reduce the effective diameter of the wheel to 27.8", for example, and the cyclometer would record 1.019 miles for each mile ridden (57). The bicycle should be ridden over the calibration course.

RELIABILITY - The cyclometer is not a precision instrument. At best it will record with an error of about 1%. This is in excess of the allowable error for reasonably accurate road course measurements. On poor roads the cyclometer measurements may be as much as 5% in excess of the actual distance traveled (40,57).

II. WALKING OR PACING

Walking or pacing was formerly widely used in measuring land. It is a rapid means of making a rough survey of distances (12).

EQUIPMENT - Material to keep records and to make a rough map, i.e. paper and pencil. Optional: a tally register, which is operated by hand to count the paces or strides. A register may be obtained which registers to either 999 (price about $4.75) or 9,999 (price about $6.25) and it may be set back to zero (59).

METHOD - Wicklund suggests the following procedure: Three or four runners are trained to walk over the course. Each man determines his average walking pace per mile by counting the number of steps in a lap of a 440 yard track. Check this at least four times to get a good average. If the course to be measured is hilly, measure off a 220 yard or 440 yard section on a hill with a steel tape and walk it both ways several times to get the number of steps required for hill walking. Practice walking this measured hill strip as well as on a 440 yard track. Generally, more steps will be needed to cover a given distance up hill. After standardizing the pace (stride), the survey is started.

Each man walks over the course and keeps a written record of the number of quarter miles paced off. These men should walk over the route a runner would run, cutting corners, straightening out curves and other legal maneuvers taken by runners to save steps (52). A road race should be laid out and run on the road, but selected sidewalks, etc. may be made officially a part of the course.

A US Army Field Manual states that the length of a man’s pace at a natural walk is about 30 inches but varies somewhat above and below this figure. Each man determines his own pace length by walking several times over a known distance. Avoid taking unnatural strides. Knowing the length of a pace or step, the measurement of a distance consists of counting steps, and keeping a tally (13).

ADVANTAGES - This simple method requires very little skill. It does require attention to details and some practice.

DISADVANTAGES - The normal pace length decreases on slopes and with fatigue.

PRECAUTIONS - Maintain the same stride length. Practice pacing over an accurately measured distance.

RELIABILITY - At best, pacing on level ground can give correctness to 3% (13). It is possible to get a precision of 1/100 with much experience. The method is far from accurate enough to be acceptable for measuring road race courses.

VARIATION - A very rough estimate of distance can be made by observing the interval of time recorded by watch, needed to travel by walking or riding from point to point. The tendency to -- either over-estimate or to under-estimate the rate of travel makes this method unsuitable for road course measurement (8,18).

III. PEDOMETER AND PASSOMETER

The Pedometer and Passometer are instruments resembling a watch. If one of these mechanical registers is not available, a tally register may be substituted.

EQUIPMENT - A pedometer has a pointer which indicates miles on a dial. It has an adjusting screw which gives the erroneous idea that the instrument might be adjusted to the individual's step length, a factor needed to convert paces into miles or fractions thereof.

A passometer confines itself to counting the number of steps taken. The operator makes his own calculations of distance covered. The instrument is delicate. The operator must avoid making jarring steps since they are capable of causing the oscillating hammer to rebound thus recording an extra pace (step), that is, one step can cause two steps to be recorded unless care is taken (15).

METHOD - The operator should standardize his pace or step length by walking over a known distance on level ground and on uneven and sloping ground (12). Some surveyors use the 3 feet pace to estimate distances but a 2.5 feet pace is recommended because it is a little less than the natural step and because 40 such paces equals 100 feet. Each two paces or double step is called a stride. Thus a 2.5 feet pace means a 5 feet stride or about 1000 strides per mile. The walker's pacing must be regular. These instruments are not useful in mountainous country. On moderate slopes up to about 10 degrees, fairly good results may still be obtained by stepping out up hill and by maintaining a steady stride length on downgrades (15).

The pedometer or passometer (or paceometer) is tested over a measured distance. The passometer is used to count the number of steps in the measured distance and the pace (step) length is determined from this information (8).

The pedometer is attached to a point near the center of the body. The jolt at each step causes a pointer to turn in one direction. The pointer is worked through a train of wheels operated by a pendulum which falls at each step, and is returned to its original position by a spring. The pointer movement is read on the dial, which is usually graduated in fractions of a mile. The pointer can be returned to zero when the reading has been taken (8).

ADVANTAGES - The pedometer or the passometer may be used at a rate of 3 to 4 miles an hour (15).

DISADVANTAGES - These interpolating instruments are not intended for precise surveying.

RELIABIITY - The pedometer and the passometer will generally give an error of 2% to 3% with careful use. They are not practical for measuring road race courses (11,12,15).

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MISCELLANEOUS

THE SURVEYOR'S CHAIN - The surveyor's chain or Gunter's chain (66' long, of 100 links at 7.92 inches each in length) is seldom used today. Originally the term "chaining" referred to this method of measurement. Today "chaining" refers to measuring with a steel tape. The surveyor's chain is durable, takes rough handling, is easily repaired or adjusted, and requires minimal care in maintenance (8). The surveyor's chain is not as accurate as a steel tape. Reliability is increased by comparing the chain with a standard measure before each use (30). Correct use of a chain will give an accuracy of between 1/500 and 1/1000 (8).

ROPE - Rope has been used for rough measurement of rugged terrain or forest paths with numerous obstacles. Rope is not suitable for measuring road running courses because it varies in length depending on its age, the weather, and the amount of stretch or tension applied (8,53).

MOBILE DISTANCE RECORDER - Jewell has described a specially built measurer in which the various sources of error in the surveying wheel have been overcome. It consists of two wheels mounted in a frame which is towed behind a car. A measuring wheel is mounted between the two running wheels and it is retracted when not in use. The number of revolutions it turns is recorded by a counter.

The measuring wheel has a pneumatic tire. It is calibrated before use and is checked afterwards. "A thin chalk line is made across the tire of the measuring wheel and the car driven very slowly forward so that as the wheel rotates a chalk mark is left on the road. The car proceeds until 10 revs of the measuring wheel have been completed and the distance between the first and the tenth mark is measured with a steel tape to one eighth of an inch. Hence the distance covered by one rev., or, if considered more convenient the number of revolutions per mile, is calculated (21)." The accuracy is +/- 1 yard per mile. The gadget has stability and weight and the measuring wheel is spring loaded onto the road so that bouncing and wobbling are eliminated. This leads to a high degree of accuracy (21).

MATHEMATICS IN ROAD COURSE MEASUREMENT (58)

Systematic errors due to incorrect tape length are eliminated by standardizing the tape and getting a correction per tape length if it is not the exact length.

A statement that two ratios (fractions) are equal is called a proportion. Any two equal ratios may be used to form a proportion. The Rule of Proportion: In any proportion the cross products are equal. We can find any one of the four terms of a proportion when the other three are given.

Example (cross multiply) 4/40 = 7/n, 4 x n = 7 x 40 4n=280, n=280/4, n = 70

Question (15) - if a 100 foot tape is incorrect the chances are that it will be short. Say it is 0.1 ft. short for 100 ft. length, you would add that increment per 100 ft. measurement. But what happens if you tape a partial length, for example 13.6 ft. for the same tape error?

Answer - Use a correction factor, in this case minus 0.001 which is found by dividing the tape shortage by the tape length 0.1/100

Multiply this correction factor, -0.001, by the total measurement, and then add this figure to your total measurement,

Example: 13.6 x (-0.001) = -0.0136

13.6 measurement<br>
+ 0.0136<br>
13.6136 ft = actual length.

In the calibrated cyclist's method of measurement, the rider rides over a measured (standard) distance to obtain a constant. The distance is measured in revolutions and fractions of a revolution. The number of spokes past or short of the counter are counted at the end of the measurement. If the wheel has 32 spokes and the striker is 2 spokes past the counter it is considered 2/32nd revolutions. The revolution counter readings are converted to actual distances by the aid of conversion tables or by the use of arithmetic (proportion).

Example of a measurement: a 1100 yard standard distance was measured twice and required 496 23/32 and 496 24/32 revolutions of the cycle wheel.

The number of revolutions needed to cover a road course was 5254 11/32 revs. The cycle was again ridden over the 1100 yards standard distance and 496 25/32 revs were required.

Mean constant 496 24/32, equals 496.75 revs.

Hence length of course is $\frac{\text{1100 yards x 5254.34 revs}}{\text{496.75 revs}}$ = 11635.2 yards

Course length = 6 miles 1075 yards.

Question - How would you set up a conversion table? - By arithmetic, 1 revolution = 2.2144 yards. Found by dividing the number of revolutions needed to cover the standard course on the bicycle into the standard distance, 1100 yards = 2.2144 yards = 496.75 revs

| No. of Revolutions | Distance traveled yards |
|---|---|
| 1 | 2.2144 |
| 2 | |
| 3 | fill in |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | 22.144 |
| 20 | |
| 30 | fill in |
| 40 | |
| 50 | |
| 60 | |
| 70 | |
| 80 | |
| 90 | |
| 100 | 221.440 |
| 200 | |
| 300 | |
| 400 | |
| 500 | 1107.200 |
| 600 | |
| 700 | |
| 800 | |
| 900 | |
| 1000 | 2214.400 |

1 spoke = 0.0692 yards
Found by dividing the total number of spokes into the value for one revolution

| Spokes | Distance in yards. |
|---|---|
| 1 | 0.0692 |
| 2 | |
| 3 | |
| 4 | |
| 5 | fill in |
| 6 | |
| 7 | |
| - | |
| - | |
| - | |
| - | |
| - | |
| - | |
| - | |
| 30 | |
| 31 | |
| 32 | 2.2144 |

After finding the values for 1 revolution and 1 spoke, multiply these by the revolutions and the spokes to get the distances measured. These could be either in yards or miles, etc. With these, other multiples of the same can be quickly interpolated (58).

REFERENCES

1. BARRY, Jack, "Way to Measure Courses," Personal Communication,
Aug. 15, 1960, Santa Barbara, California.
2. BIRCHAL, Harold F., Modern Surveying for Civil Engineers.
London: Champan & Hall, Ltd., 11 Henrietta St., W. C. a 1935.
3. BRIGHT, Bill, "Measuring Road Courses," Indiana Central College, Indianapolis, Indiana, Personal Communication, Dec. 13, 1960.
4. CAMPBELL, Robert, "Measuring A Course," Personal Communication, June 20, 1960, Watertown, Mass.
5. CERUTTY, Percy W., "As to Measurements," Personal Communication, Feb 14, 1960, Portsea, Victoria, Australia
6. CIVIL ENGINEER'S HANDBOOK, edited by Archibald DeGroot, Scranton, Penn. International Textbook Co., 1956
7. CLARK, Edwin P., "Standards of Linear Measure," Reprint: School of Mines-Quarterly, 1893.
8. CLENDINNING, James, Principles and Use of Surveying Instruments. London: Blackie and Son Limited, 1959.
9. Consumer Reports, Vol. 26, #5, p.274, May 1961
10. CORNETET, Wendell H., Methods of Measurement. Bloomington, Illinois: McKnight & McKnight, 1942.
11. DAVIS, Raymond E., M. S., C. E. Elementary Plane Surveying. New York: McGraw-Hill Book Co. Inc. 3rd Edition. 1955.
12. DAVIS, Raymond E. and Francis S. Foote, Surveying: Theory and Practice. N. Y.: McGraw-Hill Book Co. , Inc. 3rd edition. 1940.
13. ENGINEER Field Manual: Professional Papers of the Corps of Engineers, U. S. Army, #29. Parts I-VII. Washington: Government Printing Office. 1917.
14. FARRELL, Neil, "Measuring Road Courses by Car," Interviewed at Hamilton, Ontario, Canada. 1960.
15. FERGUSON, Thos., Automatic Surveying Instruments and Their Practical Uses on Land and Water. London: John Bale, Sons and Danielsson, Ltd., Oxford Hours. 1904.
16. GIRLING, Jack, "Measuring Road Courses by Car." Interviewed at Hamilton, Ontario, Canada. 1960.
17. HAMILTON, Scott, "Measuring Courses in Finland," Personal Communications, Aug. 8, 1960, and Jan. 26, 1961, Helsingfors, Finland.
18. HINKS, Arthur R., Maps and Survey, 4th edition. Cambridge: University Press. 1942.
19. JASCOURT, Hugh, "Car Measurements," Personal Communications, 1963, 1964, Arlington, Va.
20. JEWELL, John, "As Regards the Measurement of Courses," Personal Communication, Jan. 15, 1960, Ealing W.5, England.
21. JEWELL, John, Notes on the Measurement of Roads for Athletic Events, RRC of England, June, 1961.
22. KISSAM, Philip, Surveying for Civil Engineers. New York: McGraw-Hill Book Co., Inc. 1956.

23. KISSAM, Philip, C. E. Surveying: Instruments and Methods for Surveys of Limited Extent. 2nd edition. New York: McGraw-Hill Book Co., Inc. 1956.
24. LEGRAND, Rupert, The New American Machinist's Handbook. New York: McGraw-Hill Book Co., Inc., 1955.
25. Long John Nebel Radio Show (WOR), New York City, September 10, 1962, Lester DelRay, on the American automobile.
26. MACKAY, Donald R., Technical Note 195 National Bureau of Standards: "Report on Technical Investigation of Odometers." Aug. 6, 1963. Washington 25, D. C.
27. Measurement, Vol. 2, #4, Oct., 1927.
28. Measurement, Vol. 5, #3, p. 4, July, 1930.
29. Mechanic Arts Magazine, Vol. IV, #1, pp. 13-16, Feb., 1899.
30. MIDDLETON, R. E. and O. Chadwick, A Treatise on Surveying. Vol. 1, London: E. & F. N. Spon, Ltd., 1935.
31. MONTEVERDE, A. L., "Road Races Are in Measurement Most Inaccurate," Personal Communication, March 5, 1960, Los Angeles, Calif.
32. NELSON, Bert, "So They Tell Me," TRACK & FIELD NEWS, Vol. 6, #8, p. 12, Sept., 1953.
33. NEVILLE, Ernest, Hints on How to Organise and Manage an 'Open' Road Running Race. Published by Road Runners Club, England.
34. NEWTON, Arthur F. H., Races and Training. England.
35. PETERS, J. H. and J. Johnson, In the Long Run, London: Cassell & Co., Ltd. 1955.
36. PETRILLO, Paul C., "Measured Miles," Personal Communication, Jan 19, 1961, NY, NY (Automobile Club of NY Inc.)
37. PICKELS, G. W., C. E., and C. C. Wiley, C. E., Route Surveying. 3rd edition. New York: John Wiley & Sons, Inc. 1949.
38. PISANI, Stan, "A Measuring Wheel," Personal Communication. March 22, 1969. Newtown, N. S. W., Australia
39. PRENTICE, Bob, "Measuring Road Courses in Victoria, Australia," Personal Communication, June 14, 1960. Melbourne, Australia.
40. "Rapid Surveying With a Bicycle," Engineering and Mining Journal, 102:23:976, Dec. 2, 1916
41. ROBBINS, Charles A., M. D., Sample, J. D., Heinicke, Don, and W. H. Childs, "Suggestions for Improving Our Road Races." Also personal communication, Nov. 9, 1960, Middletown, Conn.
42. RUTHRAUFF, W. M., D. Sc., "Measuring Road Race Courses," Personal Communication, March 30, 1960, Philadelphia, Pa.
43. STERNER, John, "Long Distance Notes," TRACK & FIELD NEWS, Vol. 3, #4, May, 1950.
44. STERNER, John, "Surveyors," Personal Communication, Nov. 1960, Bronx, N. Y.
45. STERNER, John, "Measurement of Road Running Courses," Personal Communication, Aug. 3, 1960, Nov. 1963, and June 29, 1964. Bronx, N. Y.
46. STETSON, G. L., "Fifth Wheel," Personal Communication, Feb. 1, 1961, Wood River, Illinois (Shell Oil Co.)

47. STEVENS, F. B., "The Most Accurate Way to Measure Mileage With An Automobile," Personal Communication, Dec. 9, 1960. (Firestone Tire And Rubber Co.)
48. TAKENAKA, Shoichiro, "Measuring Road Courses in Japan," Personal Communication, Jan. 9, 1960, Tokyo, Japan.
49. TAYLOR, Bill, "Survey Speedometer," Personal Communication, Dec. 6, 1960, Los Angeles, California (Mobile Racing Representative)
50. "The Origin of the Gunter's Chain," Engineering News, Vol. 22, pp. 85-86, July 27, 1889
51. WATT, Geoff, "A Measuring Wheel," Interview: June, 1959, N. Y., N. Y. And, "The Measuring Wheel," Personal Communication, May 12, 1960, London, England.
52. WIKLUND, Bill, "Road Course Measurements," Personal Communication, June 5, 1960.
53. WILLIAMS, A. Francon, Surveying for Everyone. London: The Sheldon Press. 1925.
54. "Wind Sprints," TRACK NEWSLETTER, Vol. 7, #6, Oct. 26, 1960, pp 41-42.
55. Consumer Reports, "How Honest is Rent-A-Car Mileage?" Feb. 1963, Vol. 28, #2.
56. BRISTOW, Wm. F., Division Engineer, New York State Thruway Authority. Personal Communication, Dec. 21, 1960.
57. OSBORNE, Louis Allen, "Surveying With Bicycle and Cyclometer," Mechanics Art Magazine, Vol. IV, No. 2, March 1899.
58. McKENZIE, Gordon, "Mathematics of Road Course Measurements," Personal Communication, Aug. 4, 1964. Great Neck, Long Island, N. Y.
59. KEUFFEL & ESSER Co., 15 Park Row, New York 38, N. Y. Source of Surveying Instruments, Measuring Tapes, Field Equipment, etc.
60. JACHELSKI, Phil, "Measuring Road Race Courses," Personal Communication, Jan. 29, 1964.

Note: for revision purposes, please send all corrections and suggestions for improvement of this monograph to Ted Corbitt.