193

Bulletin 240 October, 1926

TESTING DRAFT HORSES

Photo from Wide World.
Dynamometer built for testing the maximum pulling power of horses.

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

C. F. Curtiss, Director

AGRICULTURAL ENGINEERING,
ANIMAL HUSBANDRY SECTIONS

AMES, IOWA

ANIMALS AS MOTORS

"When animals are viewed from the standpoint of machines they are wonderful mechanisms. Not only are they self-feeding, self-controlling, self-maintaining and self-reproducing, but they are far more economical in the energy they are able to develop from a given weight of fuel material, than any other existing form of motor.

While they are like the steam engine in requiring carbonaceous fuel, oxygen and water for use in developing energy, these are made to combine in the animal body at a much lower temperature than is possible in the steam engine, and a much smaller proportion of the fuel value is lost in the form of heat, when work is being done."

King, F. H., 1907 Physics of Agriculture, Page 487.

195

TESTING DRAFT HORSES

BY E. V. COLLINS AND A. B. CAINE *

Horse breeders, horse users, harness and implement manufacturers and those engaged in allied industries have often wondered about the maximum working and overload capacity of horses. What is the output of horses in ordinary work and what can they do in emergencies?

This bulletin gives the results of experiments conducted to determine the work capacity of horses and then to answer those questions in part, and to describe the apparatus used and the methods followed in conducting these tests.

Many attempts were made by early investigators to determine the working capacity of horses and some tried also to find out the reserve or overload capacity of a well trained horse.

HORSE POWER

The term "horse power" is the commonly accepted unit of power or rate of doing work and is the equivalent of 33,000 foot pounds of work performed in one minute. Horse power is calculated by multiplying the force acting in pounds by the distance thru which it moves in feet per minute and dividing the result, which is foot pounds per minute by 33,000 the number of foot pounds established as the unit of horse power.

As an example, if a horse exerts a tractive pull of 175 pounds while traveling at the rate of 2½ miles per hour (220 feet per minute) the foot pounds of work per minute equals 175 times 220 or 38,500. Dividing 38,500 by 33,000 the horse power developed is 1 1/6.

Contrary to general opinion, Watts' estimate of the ability of a horse based on his tests was not one horse power, as he established the unit, but only two-thirds of that amount. This is explained by the following paragraph taken from the U. S. Bureau of Standards Bulletin No. 34.

"The unit of horse power employed at the present time in measuring the work performed by machines, was originated by James Watt, who is credited with the first practical steam engine. When Watt began to place his steam engine on the market it became necessary to have some unit by which its capacity could be designated, and as the work to which the engine was first put had previously been done, for the most part, by horses, it was natural that the work of the engine should be compared with that of horses. The value of the horsepower was arrived at experimentally by

*Cooperating with the Horse Association of America, Wayne Dinsmore, Secretary. Acknowledgment is made to Mr. Dinsmore for his valuable aid in planning these tests and in promoting the pulling contests and to the the Horse Association of America for financial assistance.

Watt and his business partner, Boulton. Some heavy draft horses were obtained from the brewery of Barclay and Perkins, London, and were caused to raise a weight from the bottom of a deep well by pulling horizontally by a rope passing over a pulley. It was found that a horse could conveniently raise a weight of 100 pounds attached to the end of the rope while walking at the rate of two and one-half miles per hour, or 220 feet per minute. This is 220 x 100—22,000 foot-pounds. Watt, however, in order to allow for friction in his engine and for good measure added 50 per cent to this amount, thus establishing 33,000 foot-pounds per minute, or 550 foot-pounds per second as the unit of power."

This unit of power is now used to rate all forms of mechanical motors, steam engines, gas engines, electric motors and water power developments.

ESTIMATE OF AUTHORITIES ON THE ABILITY OF HORSES TO DO WORK

Desaguliers[1]	8 hrs. 200 lbs. @ 2½ m. p. h.*		1.33 H. P.
M. Sanver[1]	189 lbs. 3 ft. per sec.		1.5 H. P.
Desaguliers[1]	550 lbs. 50 ft. per min.		.84 H. P.
Smeaton[1]	550 lbs. 40 ft. per min.		.67 H. P.
Society of the Encouragement of Arts[1]	80 lbs. 3 m. p. h.		.64 H. P.
Tredgold[1] 6 hrs.	125 lbs. 3 m. p. h.		1 H. P.
King[2]	1,600-lb. horse		1.06-1.33 H. P.
Watt[3]	100 lbs. 2½ m. p. h.		.67 H. P.
Simms[4]	8 hrs.		.8 H. P.
Rennie[4]			.67 H. P.
Beardmore[4]			1.19 H. P.
Max. power developed at Iowa State College Experiments		1922	1.39 H. P.
		1923	1.27 H. P.
		1924	1.42 H. P.
Max. power developed per horse in pulling contests— 27½ feet			14.88 H. P.

APPARATUS USED IN CONDUCTING TESTS

Before starting tests to determine the ability of horses to do work it was found necessary to devise a new type of testing apparatus especially adapted to furnish a uniform resistance for the horse to pull against.

The draft required for the ordinary equipment drawn by horses varies so much that it is impractical to use such equip-

*M. P. H. stands for miles per hour.

[1]Appleton's Dictionary of Mechanics, New Edition, 2 vol. 1869.

[2]King, F. H. Physics of Agriculture, 1907.

[3]Dept. of Commerce, The Relation of the Horse Power to the Kilowatt, Cir. of Bureau of Standards 34. 1912.

[4]Clark, D. K. A Manual of Rules, Tables and Data for Mechanical Engineers, 1902.

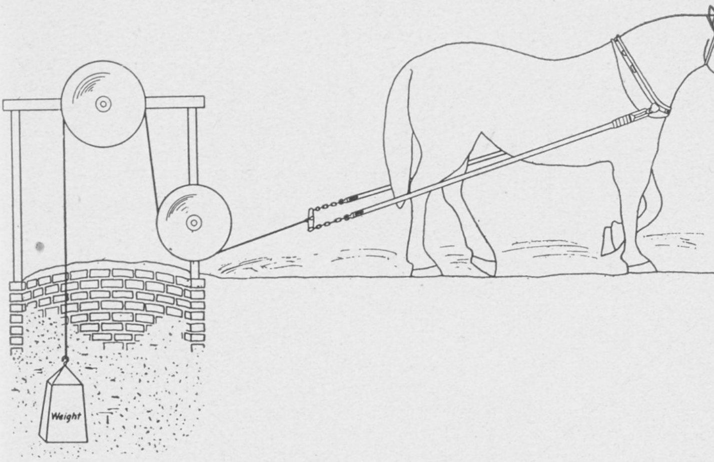

Fig. 1. First apparatus used to test the draft of horses.

ment as test loads because the amount of work done could not be measured accurately.

In the tests made by Watt and Boulton, as well as by some other experimenters, the horses were hitched to a rope which passed over a pulley and lifted a weight from a well (fig. 1). This scheme is not entirely practicable because the length of pull is limited to the depth of the well, the angle of trace will vary unless a horizontal hitch is used, and a frictionless pulley does not exist.

The apparatus developed for these tests utilizes the same principle of lifting weights as in the earlier tests, but the other objections have been overcome. Fig. 2 illustrates a simple device for testing one horse in connection with a three-horse road drag or other implement. The center horse is hitched to a cable which passes around two pulleys and is attached to a weight. In operation the center horse keeps this weight suspended and in so doing exerts a force equal to the weight, tending to move the implement forward. The remaining tractive force required to move the implement is furnished by the other two horses, and necessarily varies with any change in tractive resistance of the implement, while the pull or force exerted by the center horse will remain constant and equal to the weight suspended. Such an apparatus, while accurate for the testing of one horse, has the disadvantage of requiring the service of two other horses. It is shown here in order that it may help the reader to understand the action of the machines which were used in these tests.

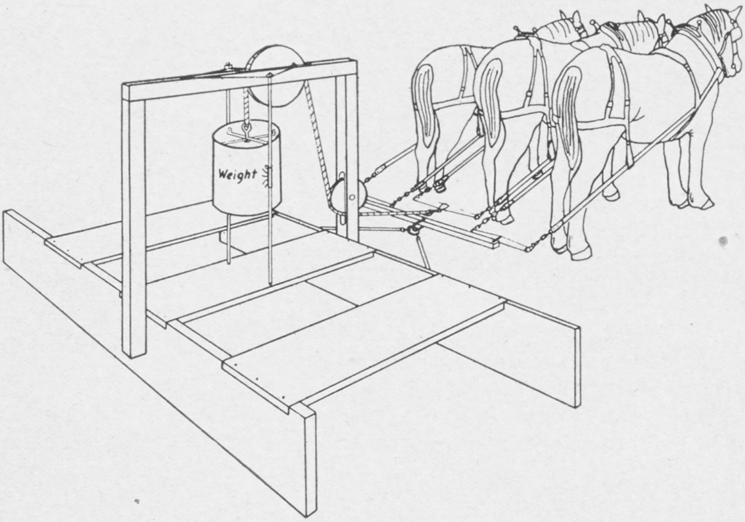

Fig 2. Simple method of applying a definite uniform load to the center horse.

THE FIRST DYNAMOMETER

In the first dynamometer (figs. 3 and 4), built for this work, provision was made for hitching each of two horses to weights in a manner similar to that shown in fig. 2. In this case the tractive pull resulting from lifting the weights is more than enough to propel the dynamometer and it is necessary to apply some resistance to hold the machine back. This was done by gearing the rear wheels to a rotary pump and then regulating the discharge from the pump to produce the desired resistance. This regulation was made automatic by connecting the valve so that it is operated by a change in the height of the weights relative to the frame.

When the weights are at the bottom the valve is closed and the rear wheels are locked. As the weights are lifted the valve gradually opens until at the top it is wide open and the pump furnishes a minimum of resistance. In action this automatic control allows the dynamometer to move just fast enough to keep the weights suspended whenever the team is moving. The condition of the road surface or the grade does not affect the amount of work done by the team but merely requires that more or less resistance must be furnished by the pump. The tractive pull exerted by the team is constant and equal to the sum of the weights which are held suspended.

In action, then, the tractive force required to move the dynamometer (variable) plus the resistance furnished by the pump (governed by position of weights) is equal to the tractive pull exerted by the team (constant). The dynamometer, of course, has practical limits. On slippery roads it is difficult to get enough traction for the wheels in which case the weights would not be lifted and the team would be exerting a tractive force something less than the weights. On the other hand, where the roads are extremely soft or a very steep hill is encountered, it is quite possible that the tractive pull required to move the machine itself will be greater than the amount of the weights. This may readily occur if only a light load were applied. In such a case the weights would strike the top of their guides and the team would be exerting a greater tractive pull than the amount of the weights.

The dynamometer as built was equipped to furnish a tractive resistance for each horse which could be varied from 60 to 350 pounds.

LARGER MACHINE IS BUILT

In order to test horses for their maximum effort for short periods, a larger machine was built. This dynamometer is

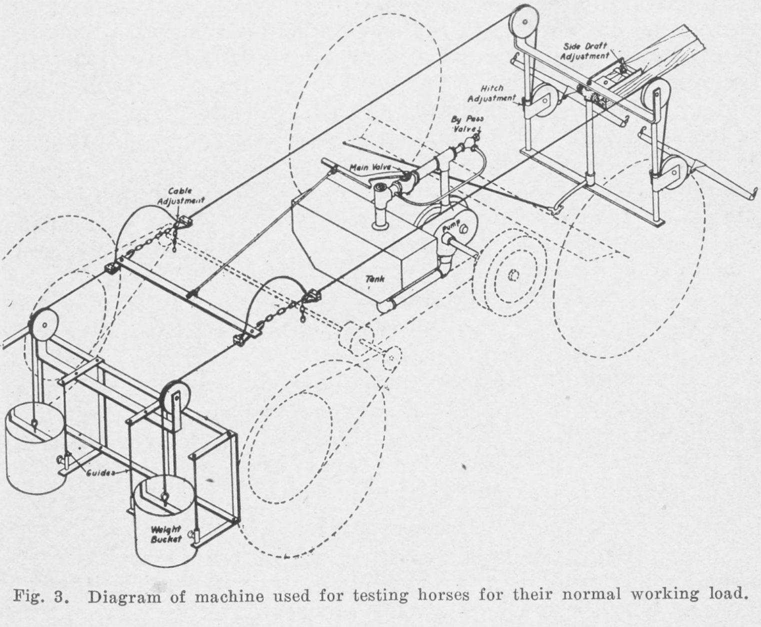

Fig. 3. Diagram of machine used for testing horses for their normal working load.

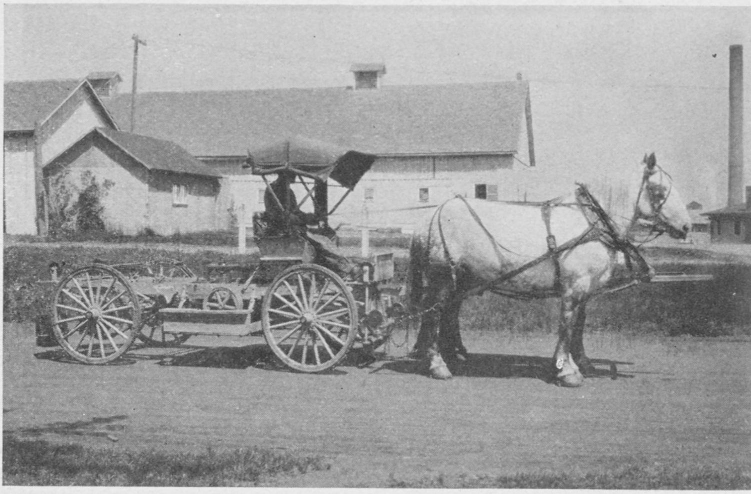

Fig. 4. Dynamometer built for testing horses at normal working load.

shown in figs. 5 and 6. This operates in essentially the same way as the smaller machine just described but differs in constructional details and in capacity. In the construction of the machine, the chassis of a Nash quad four-wheel drive truck was used. The engine of the truck was replaced with a rotary pump so that the same train of gearing could be used to drive the pump. The team in this case is hitched to a double tree and only one set of weights is used. The weights are made of reinforced concrete and normally rest upon the frame as shown. Each of the weights may be attached to the weight beam by turning a lock on the beam. The valve controlling the discharge from the pump is so connected to the weight beam that the valve is closed when the beam is at the bottom of the guides and open when the beam is at the top. By this means the forward movement of the truck is regulated automatically so that the weights will always be lifted while the dynamometer is in motion. This machine has a maximum capacity of 4,100 pounds tractive pull and a total weight of 10,000 pounds.

THE SECOND LARGE MACHINE

The machine shown in figs. 7 and 8 was also built for testing horses for their maximum effort. It is mounted on the rear of a Ford truck chassis and as the engine was not removed, the truck can be readily transported with its own power. The large weights used are cast iron disks weighing

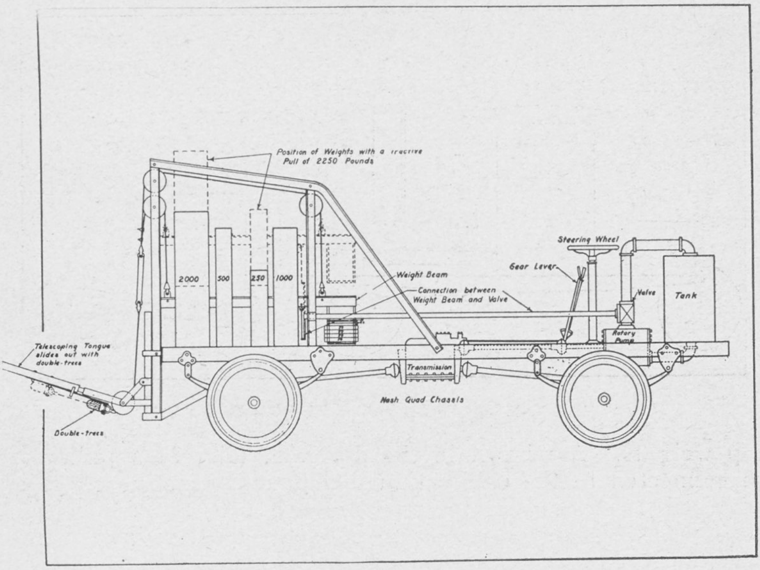

Fig. 5. Diagram of first dynamometer, built to determine maximum effort of teams. This type of apparatus has been patented and assigned to the College.

250 pounds each. As many of these as desired may be attached to the lifting cable. Small increments of weight may added by placing them in the space provided between the two

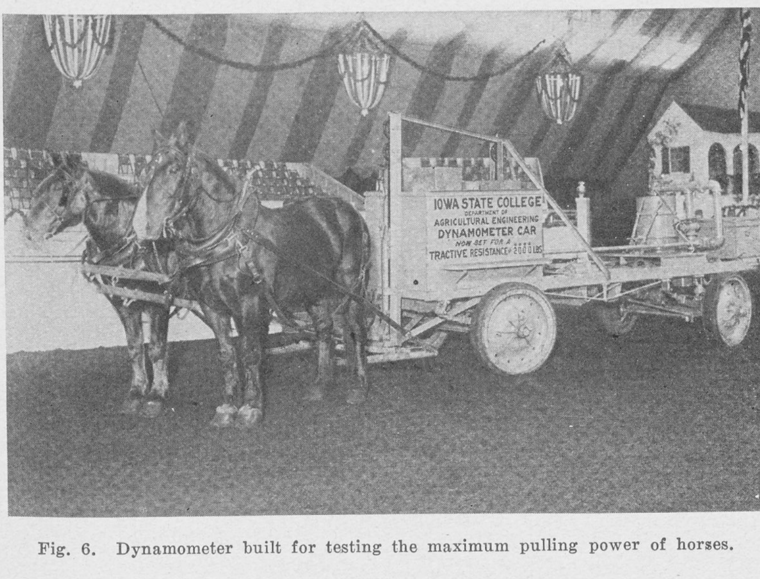

Fig. 6. Dynamometer built for testing the maximum pulling power of horses.

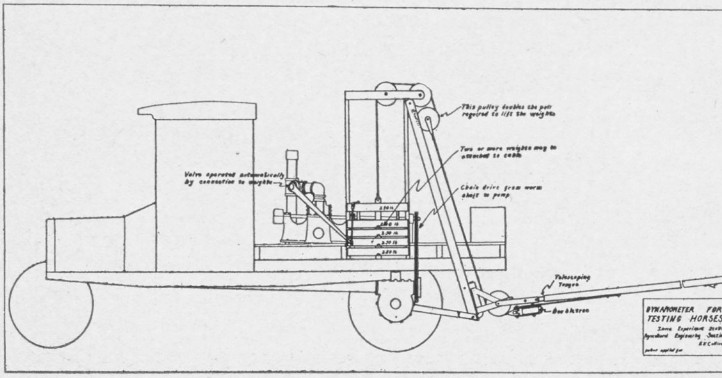

Fig. 7. Diagram of dynamometer built on Ford chassis.

top weights. As shown in the diagram, (fig. 7) a pulley is so connected to the cables that 500 pounds tractive effort is required on the hitch to support each 250 pounds weight. This was necessary in order to keep the total weight of the machine as low as possible. A special sprocket attaches to the rear of the worm shaft and drives the pump by means of a roller chain. The lever operating the pump discharge-valve is connected to the weights so that the valve is closed when the weights are resting on the frame and wide open when the weights are at the top of their guides. By this means, just enough resistance is automatically applied at all times to the forward movement of the dyamometer to keep the weights suspended. The height at which the weights are carried de-

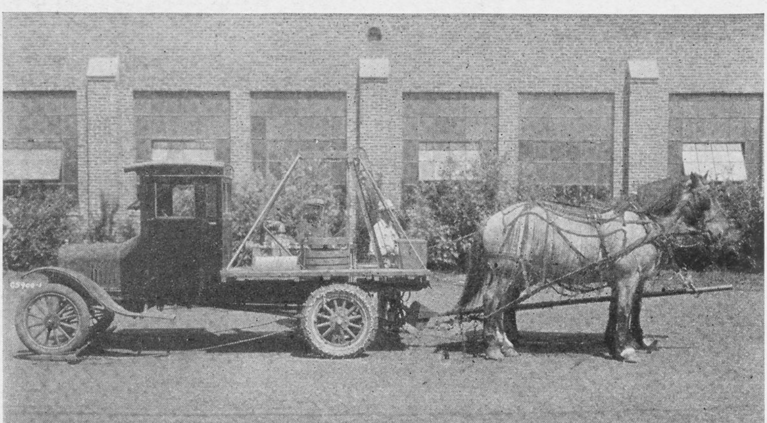

Fig. 8. Dynamometer built on Ford ton truck.

pends upon the speed of the team, the amount of weights attached and the road surface, but is of no importance as long as the weights are not touching either the top or bottom of the guides.

This machine has a maximum capacity of 3,200 pounds tractive pull and a total weight of 5,230 pounds. In order to get enough traction for average road conditions, it is necessary to use skid chains on the rear wheels and to put a skid under the front wheels as shown in fig. 8. For loads very near the maximum, additional weight is applied to the truck body. This is usually accomplished by getting men to stand on the platform.

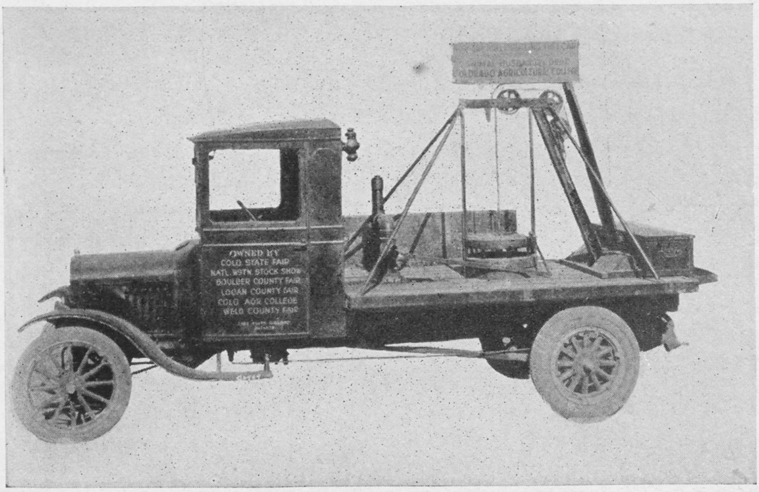

Fig. 9. Dynamometer built for the Colorado State College.

For transportation it is only necessary to disconnect the tongue and skids, load them on the platform and take off the roller chain which drives the pump.

This type of machine has been further improved by the addition of a three-speed auxiliary transmission with power take off attachment. This provides six forward speeds for transporting the machine and the power take off provides a more suitable method of driving the pump, otherwise no important changes have been made. The machine is illustrated in fig. 9.

INTEGRATING TRACTION DYNAMOMETER

The instrument used to determine the draft or tractive effort necessary to pull wagons and various farm equipment is illustrated in figs. 10 to 16 and is known as the "Iowa In-

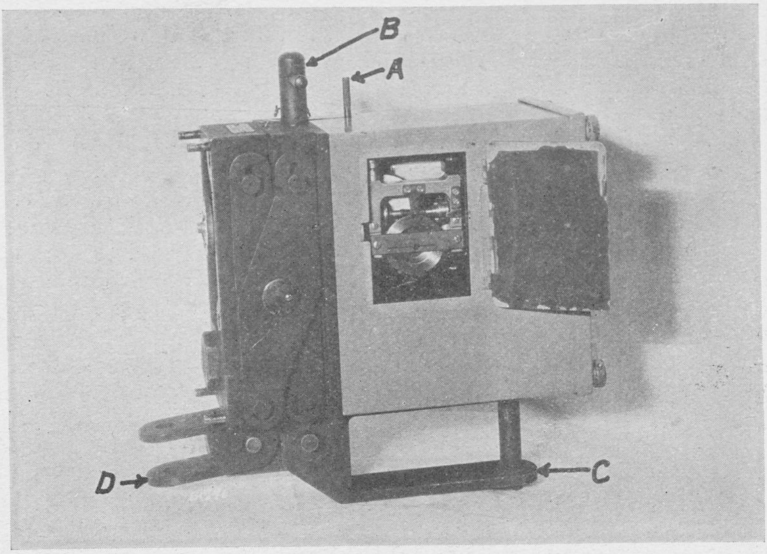

Fig. 10. Iowa Integrating Dynamometer. A. Lever to engage clutch. B. Handle. C. Evener clevis. D. Implement clevis.

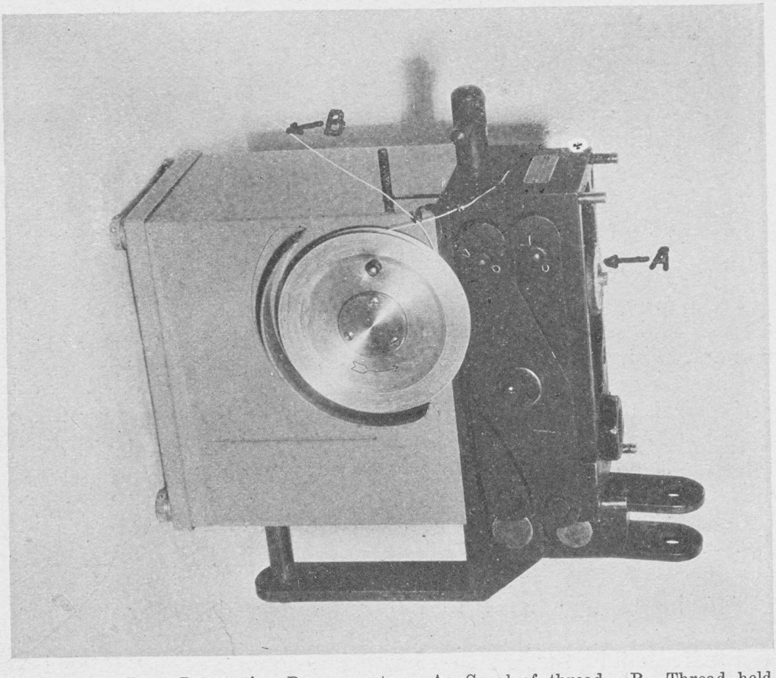

Fig. 11. Iowa Integrating Dynamometer. A. Spool of thread. B. Thread held stationary while making test.

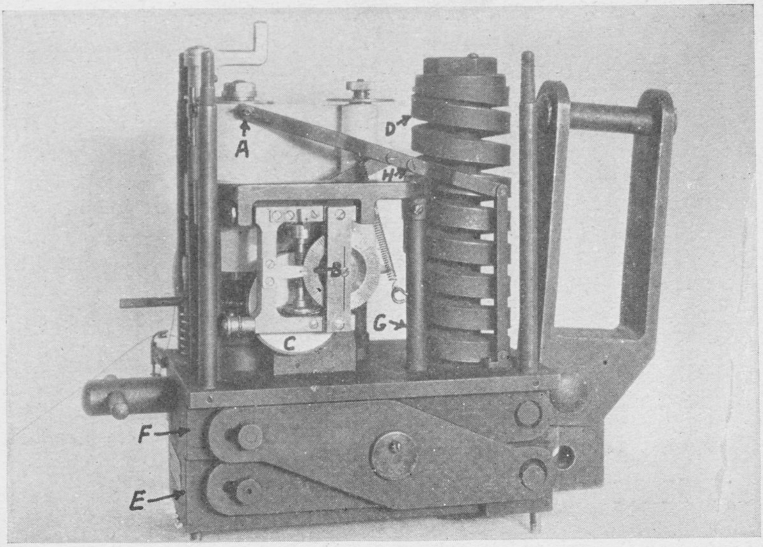

Fig. 12. Dynamometer with cover removed. A. Recording pencil. B. Integrator. C. Revolving disc. D. Spring which tends to hold frame together. E. Lower frame. F. Upper frame. G. Integrator support attached to lower frame. H. Pencil motion attached to lower frame.

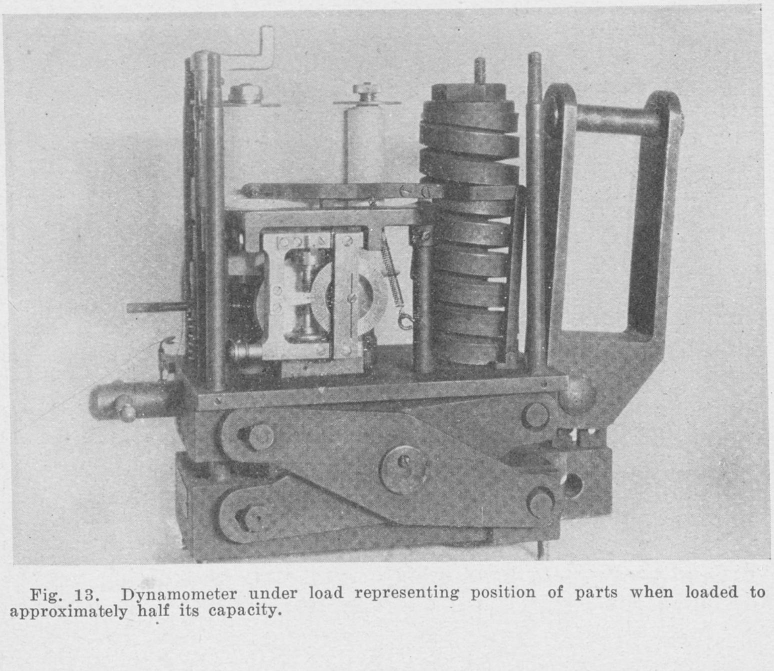

Fig. 13. Dynamometer under load representing position of parts when loaded to approximately half its capacity.

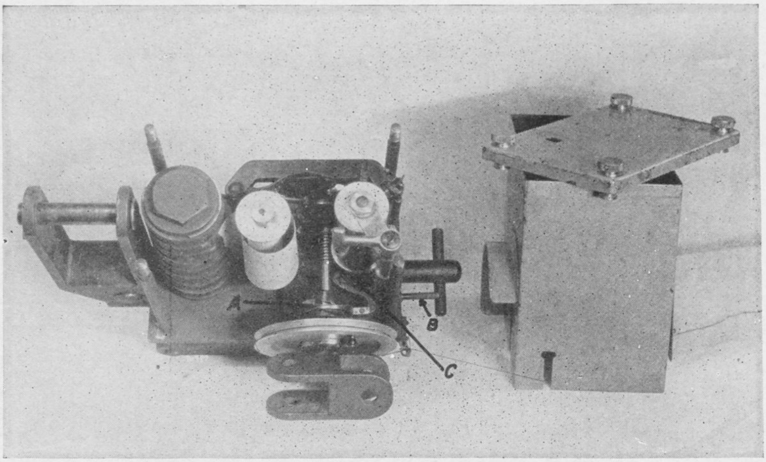

Fig. 14. Top view of dynamometer. A. Clutch. B. Lever to engage clutch. C. Cam to disengage clutch.

tegrating Traction Dynamometer.'' It was developed by the Agricultural Engineering Section of this Station. By means of the instrument it is possible to determine quickly the average draft or tractive effort required to pull any implement or vehicle. The frame of the machine is in two parts, normally held together with a heavy compression spring. These two parts are so connected with levers that they will remain parallel as they are separated by the tractive force when the instrument is used. The upper part of the frame serves as a mounting for the gearing and recording mechanism. The lower part of the frame is so connected to the pencil motion and integrator that the movements of this part of the frame, relative to the other part will be recorded graphically on the roll of paper and averaged by the integrator. The details of the pencil motion are shown in figs. 12 and 13. It is operated by a connecting link which attaches to the lower frame. The linkage of the pencil motion is such that the pencil point moves in a straight line across the record and not in the arc of a circle.

The paper drum is driven by a worm gear with 50 to 1 ratio. The worm shaft carries at one end a grooved wheel connected to the shaft by a clutch (fig. 14) and at the other end a flat disk. In operation a thread is wrapped around the grooved pulley and either held by an attendant or fastened to a stake. As the machine moves forward the thread causes the grooved wheel to rotate in proportion to the distance covered. When the operator wishes to start a test the clutch is engaged and the worm shaft and paper drum start to rotate. The clutch is so arranged that it will be automatically disengaged when the paper drum has made one complete revolution. This is accomplished in 50 feet of travel.

The integrator operates on the flat disk carried by the worm shaft. The integrating wheel normally rests just below the center of the disk but as the two parts of the frame are separated the integrating wheel is moved nearer the circumference and will be rotated at a higher speed relative to the speed of the worm shaft.

It is obvious, then, that the greater the tractive force applied to the dyamometer the farther the two parts of the frame will separate and the larger will be the number of revolutions made by the integrating wheel for a given number of revolutions of the driving disk, figs. 12 and 13. Since the number of revolutions made by the driving disk during one test is always the same, namely, 50 revolutions, the number of revolutions made by the integrating wheel will be proportional to the average draft during the test. The instrument is calibrated in a testing machine and then it is only necessary to

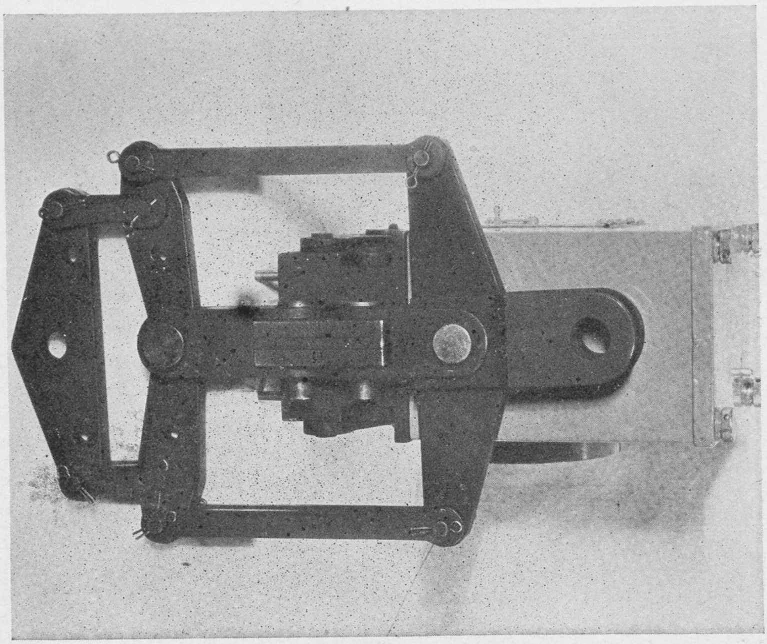

Fig. 15. Multiplying hitch attached to dynamometer set to increase capacity four times.

refer to a calibration curve to determine the average draft corresponding to a given integrator reading.

The graphical record made by the pencil on the strip of paper is valuable in indicating the variations in draft and while the average draft can be determined approximately from the graphical record the integrator gives the result more accurately and much quicker.

The instrument when connected directly has a capacity up to 2,500 pounds tractive pull and by the use of the special hitch shown in fig. 15 this may be increased to 5,000 pounds or 10,000 pounds.

DRAFT OF FARM EQUIPMENT

Table I gives the results of draft tests on a few items of farm equipment, and while such tests would vary with different conditions they will give a general idea of the tractive pull required of horses in field work. These tests were made in the vicinity of Ames on soils classed as clay loams.

Plowing requires more power than any other one farming operation and probably the draft required to pull a plow varies more than that of any other farm implement. The draft of a 14 inch plow may vary from 150 to 1,800 pounds per bottom. This variation is due to variations in the type of soil, physical condition of the soil, crops grown, depth of plowing and amount

Fig. 16. Integrating dynamometer attached to implement.

TABLE I. DRAFT TESTS OF VARIOUS ITEMS OF FARM EQUIPMENT

Implement	Draft lbs.	*Remarks*	No. horses recommended
14″ Sulky plow	500	6″ deep sudan grass	3
14″ Sulky plow	500	5″ deep bluegrass seed	3
14″ Sulky plow	420	7″ deep stubble	3
14″ Sulky plow	520	6″ deep corn stubble	3
14″ Sulky plow	480	4″ deep sod	3
14″ Gang plow	760	5″ deep corn st'ble } same soil	4-5
14″ Gang plow	1,380	5″ deep Alfalfa } same soil	7-8
14″ Gang plow	645	6½″ deep sand	4
14″ Gang plow	850	6½″ deep black soil	5-6
8′ 16″ Disc harrow	400	Corn stubble	3
8′ 16″ Disc harrow	450	Bluegrass sod	3
8′ 16″ Disc harrow	550	Plowed sod	4
10″ Disc harrow	590	Fall plowing	4
10″ Disc harrow	650	Corn stubble	4-5
9″ Disc harrow	565	Corn stubble	4
24′ Smoothing harrow	740		4-5
7′ Cultipacker	300		2
2 Row cultivator	540	3½″ deep	3-4
2 Row cultivator	300	2½″ deep	3
Mower 5′	182½	Light alfalfa }	2
Mower 5′	200	Heavy alfalfa }	
Low wheeled wagon and hay loader	600		3-4
Corn binder	320		2
Single row stalk cutter	160		1-2
Disc drill—10x8 double discs	210		2
Disc drill—18x7 single discs	400		3-4
Disc drill—12x7 single discs	182		2

of moisture present. Aside from these factors the condition and adjustment of the plow will also influence the draft.

The effect of the difference in crops is well illustrated by tests No. 6 and 7 which were made in the same field. The 14 inch gang plow required 760 pounds tractive effort to pull it in the corn stubble and 1,380 pounds in the alfalfa. Four good horses could handle this plow in corn stubble, but in the alfalfa seven or eight should be used. If the size of team is limited to four horses, then one bottom only should be used. Experiments have shown that the draft of a plow is practically in proportion to the depth. As an example if a four horse team is the proper unit for plowing 4 inches deep with a 14 inch gang then one horse should be added for every additional inch in depth of plowing.

DRAFT OF LOADS ON CITY STREETS

Tests to determine the drafts of loads on city streets were made in Chicago with the co-operation of the Horse Association of America. With representative teams and loads tests were made on as many types of paving as were convenient. In all cases draft tests were made in both directions, or the grade was checked with a level, in order to prevent the grade from influencing the draft.

It will be noted (table II) that these teams do much less actual work than farm teams doing field work. On the other hand, a greater reserve is required of city teams to enable

TABLE II—LOAD PULL TESTS—WEEK OF SEPTEMBER 17-22, 1923, CHICAGO, ILLINOIS

Made by E. V. Collins, Agricultural Engineering Department, Iowa State College and Experiment Station, Co-operating with Committee on Animal Motive Power American Society of Agricultural Engineers and Horse Association of America, Union Stock Yards, Ill.
Character of Roads and Pounds Tractive Pull Required

OWNER OF TEAM AND KIND OF LOAD	Wt. harnessed team	No. horses	Total wt. wagon & load	Granite blocks			Concrete			Asphalt			Brick			Steel rails			Wood blocks		
				A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Consumers Co. Ice, 15—300-lb. cakes	1725	1	6,700	950	30	9	-----	-----	-----	1200	120	36	-----	-----	-----	410	30	9	820	43	13
Western News Co.—Magazines	1600	1	4,800	800	60	25	970	20	8.5	1200	80	33	-----	-----	-----	-----	30	12	-----	-----	-----
A. T. Willet Co., Mixed Merchandise	3200	2	13,540	1200	143	20.5	980	93	13.6	1300	337	50	-----	-----	-----	-----	-----	-----	1250	180	26.5
Consumer's Co., Coal	2800	2	14,300	980	85	12	1160	100	14.5	1500	400	56	1000	105	15	850	37	5.2	-----	-----	-----
Carpenter Coal Co., Coal	3400	2	16,300	1620	200	24.5	-----	-----	-----	1800	380	46.5	-----	-----	-----	-----	-----	-----	1430	225	27.5
Olson Cartage Co., Sacked Feed**	3500	2	14,900	2400	170	23	-----	-----	-----	-----	315	42.5	1650	160	21.5	-----	-----	-----	-----	-----	-----
American Railway Express, Mixed Heavy Mdse.	3310	2	10,285	980	100	19.5	-----	-----	-----	1000	235	42	-----	230	42†	-----	-----	-----	1300	150	29
Oscar Mayer & Co., Packed Meats in Boxes and Bbls.	3110	2	6,920	215	60	17	-----	-----	-----	490	160	46.5	-----	-----	-----	-----	25	7.2	-----	-----	-----

Western News Co.— Magazines	3800	2	13,000	900	150	23	-----	-----	-----	1500	290	44.5	-----	-----	-----	-----	-----	-----	-----	-----	-----
Consumer's Co., Ice, 23—300-lb. cakes	3200	2	11,000	820	50	9	-----	-----	-----	1140	305	52	-----	-----	-----	820	40	7.2	980	90	16
Arthur Dixon Trans. Co., Mixed Mdse.	3500	2	9,800	1000	145	29.5	-----	-----	-----	1000	225	46	-----	-----	-----	-----	-----	-----	-----	-----	-----
Arthur Dixon Trans. Co., Paper	2800	2	12,370	950	210	34	-----	-----	-----	1300	360	59	-----	-----	-----	-----	-----	-----	-----	-----	-----
Wis. Lime & Cement Co., Stone and Cement	3500	2	10,100	-----	-----	-----	-----	-----	-----	1050	280	56	1400	100	20	-----	-----	-----	-----	-----	-----
A. T. Willett Co., Barreled Products	5250	3	20,150	1750	300	30	1450	160	16	2450	540	54	-----	-----	-----	-----	-----	-----	1650	255	25.5
Bunge Bros., Coal	5650	3	20,750	1600	240	23	-----	-----	-----	1950	480	46	-----	-----	-----	200	50	4.8	-----	-----	-----
Arthur Dixon Trans. Co., Hides	4700	3	22,880	2450	320	28	-----	-----	-----	3300	475	41.5	-----	-----	-----	-----	-----	-----	-----	-----	-----
Average	--------	--------	--------	-----	-----	22	-----	-----	14.7	-----	-----	47.3	-----	-----	18.8	-----	-----	7.6	-----	-----	21.7

*On concrete and asphalt tests horse happened to be excited and pulled on bit, reducing tractive pull below what it would have been normally.

NOTE A—Tractive Pull necessary to start load when standing still.
B—Tractive pull required to draw load over road after it is once in motion.
C—Tractive pull required per ton to draw load after it is once in motion.

†Bricks were covered with silt dirt, hence traction abnormally high.

**One test with this team and load was made on dirt road. Tractive pull necessary to start the load, 2,600; tractive pull required to draw loads after once in motion, 640 and tractive pull required per ton to draw load after once in motion, 86.

them to start very large loads and to pull thru unpaved alleys or over grades. In considering the size of loads hauled in these tests it is well to keep in mind that Chicago is very completely paved and very level. Practically all grades of consequence are artificial, such as approaches to viaducts, bridges and ramps.

The extremely low draft recorded for teams Nos. 10 and 11 on granite block pavement may be explained by the fact that the pavement used in this case was very smoothly laid and was supported by the extremely heavy foundation of the street car tracks.

PULLING CONTESTS

In order to secure data on the maximum pulling power of horses, arrangements were made to conduct pulling contests in cooperation with various fairs and horse shows. In most cases the teams entered in these contests were divided into two classes; namely, teams weighing less than 3,000 pounds and teams weighing 3,000 pounds or more. In some instances another class was made for teams over 3,500 pounds. Contests were conducted in the following manner:

The dynamometer was set for a tractive resistance which any good pulling team in this class could be expected to handle. A starting load of 1,500 pounds was used most frequently. Each team in turn was required to pull the dynamometer set at this resistance for the full standard distance of 27½ feet without stopping. If a team failed at the first trial, it was permitted two more trials at the same setting. After all teams had either successfully completed this test or failed after three trials, the tractive resistance of the dynamometer was increased by attaching more weight and the teams again tested in turn. This process was continued until all teams excepting possibly one were eliminated by either failing to make the full distance or failing to start the dynamometer in the three trials. The placing of the teams was based, first, on the maximum load pulled the full distance; second, on the team making the greatest distance in one pull where two or more teams fail to make the full distance with a given load; and third, in case of tie the time required to complete the largest pull made for the full distance. For obvious reasons, drivers were not allowed to use whips on their horses and shouting was not permitted. Aside from the value of the data secured in these tests, their competitive nature makes a very desirable attraction for fairs and livestock shows, and there are prominent educational features both in demonstrating the maximum ability of horses and in promoting good horsemanship.

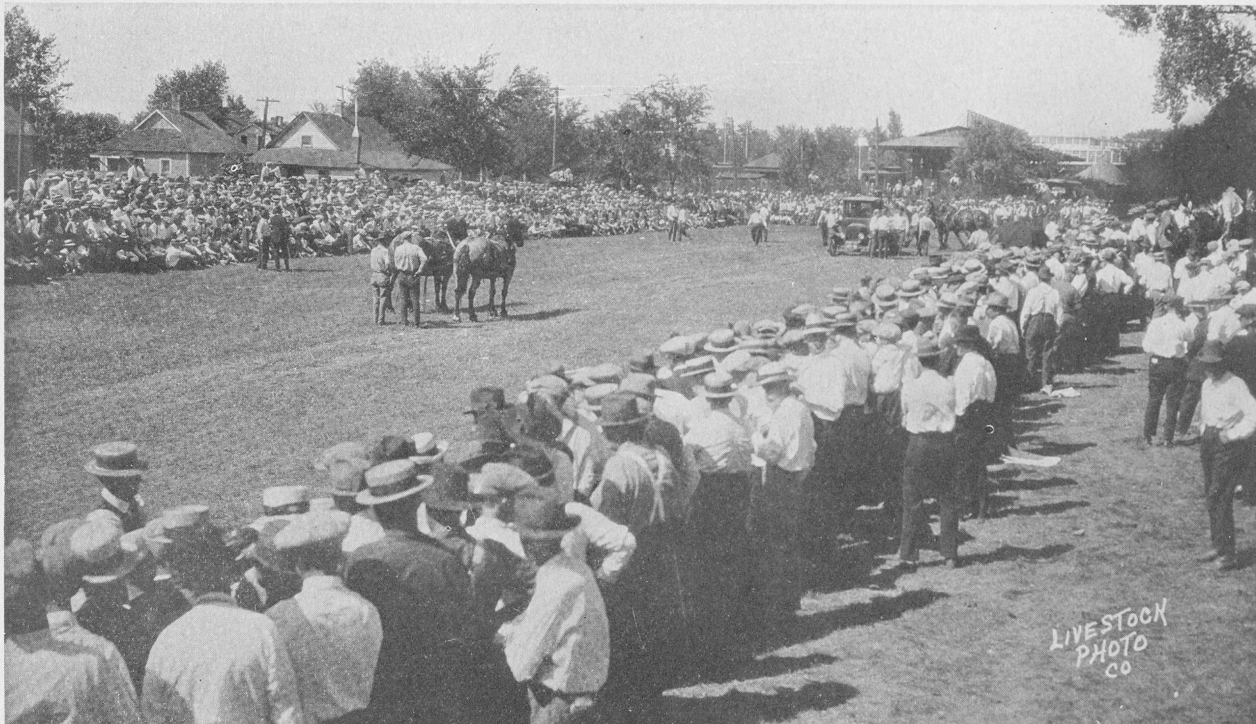

Fig. 16. Pulling contest at the Iowa State Fair.

TABLE III—AWARDS IN HORSE AND MULE PULLING CONTEST
IOWA STATE FAIR, 1923

Class 1—Farm Team Weighing Under 3,000 Pounds

	Name	Sex	Age	Wt.	Breed	Maximum pull exerted (Lbs.)	Length of pull	Owner
1st	Bess	M	8	1405	Grade Shire	2050	50 ft.	John Donaghy, Slater, Iowa
	Florence	M	8	1460	Grade Shire	2100	15ft.-9 in.	
2nd	Dan	G	5	1420	Grade Belgian	2050	50 ft.	J. S. Peters, Adelphi, Iowa
	Dick	G	5	1515	Grade Belgian	2100	4 ft.	
3rd	Bill	G	11	1400	Unknown	2000	50 ft.	A. Richardson, Ankeny, Iowa
	Ned	G	11	1590	Unknown	2050	35 ft.-8 in.	
4th	Babe	M	6	1400	Grade Perch.	2000	50 ft.	P. L. Stewart, Valley Junc., Iowa
	Dutch	M	6	1360	Grade Perch.			
5th	Dan	G	8	1165	Broncho	2000	40 ft.	Keefer & Hamilton, Harrisonville, Mo.
	Jim	G	9	1140	Broncho			

Class 3—Teams Weighing Over 3,000 Pounds

	Name	Sex	Age	Wt.	Breed	Maximum pull exerted (Lbs.)	Length of pull	Owner
Tied for 1st and Championship	Cap	G	10	1725	Grade Perch.	2300	25 ft.	C. C. Taft & Co., Des Moines, Iowa
	King	G	10	1905	Grade Perch.			
	Jim	G	6	1680	Grade Clyde.	2300	25 ft.	Merchants Transfer & Storage Co., Des Moines, Iowa
	Bill	G	10	1680	Grade Shire			
3rd	Prince	G	7	1610	Unknown	2100	50 ft.	White Line Transfer & Storage Co., Des Moines, Iowa
	Tom	G	9	1675	Unknown			
4th	Jerry	G	9	1550	Grade Shire	2100	45 ft.	Des Moines Ice & Fuel Co., Des Moines, Iowa
	Tom	G	10	1480	Grade Shire			
5th	Tip	G	12	1820	Grade Perch.	2100	36 ft.-7 in.	Merchants Transfer & Storage Co., Des Moines, Iowa
	Doc	G	8	1745	Grade Perch.			

The standard distance of 27½ feet was selected in order to simplify the computation of horse power developed for any test. Using this distance the horse power can be determined by dividing the tractive pull by two times the number of seconds required to complete the distance and divide this result by ten. As an illustration, if a team pulls the dynamometer set at 1,800 pounds for the full distance (27½ feet) in 5.2 seconds the horse power developed is

$$\frac{1800}{5.2 \times 2 \times 10} = 17.3 \text{ H. P.}$$

In most instances a team does not develop the maximum horse power while pulling the maximum load. This is because the team is slowed down when putting forth a maximum effort.

The following record of the different pulls made by the winning team in the heavyweight class at the Iowa State Fair in 1925 will illustrate this point.

Trial No.	Distance	Duration of trial	Tractive pull	Horse power
1	27½ ft.	4	2,000	25
2	27½ ft.	4.2	2,500	29.76
3	27½ ft.	11	3,000	13.6
4	27½ ft.	8	3,200	20
5	27½ ft.	11	3,400	15.45
6	27½ ft.	9.8	3,425	17.5

In trials 3 and 5, especially, low records were made because the team pulled more slowly. No attempt was made to hurry the team in these tests because the contest was based on maximum pull rather than maximum horse power developed.

WHAT THE CONTESTS HAVE DEMONSTRATED

The pulling contests have demonstrated many things of practical value to horsemen. It has been demonstrated clearly that training plays a very important part in securing maximum results from horses. In several instances teams have entered contests and exerted what seemed then to be their maximum pulls. In succeeding contests, where a little special training had been given, often these same teams have been able to pull much larger loads. The value of weight has also been emphasized markedly. Records show clearly, with teams that have been tested when they were thin and again when they were in higher condition, that they were able to pull larger loads when they were fatter and heavier. Their ability to do this may have been due to the extra weight which gave them better footing. It is also possible that additional fat may have toned up or improved their muscular system.

The contests also have demonstrated the value of proper fitting collars and harness, but the collars are of greatest importance. Ill-fitting collars may prove a distinct handicap when a horse is exerting a maximum effort. A collar that is too short interferes with normal breathing and may be the

TABLE IV—RESULTS OF VARIOUS PULLING CONTESTS

IOWA STATE COLLEGE SHORT COURSE, JANUARY 30, 1924

(Team weighing over 3,000 pounds)

Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
Major	G	7	1570	*2500	27½ ft.	Lew Cole
Beauty	M	11	1720			

*Highest record made until the summer of 1924.

CONTEST, GREENE COUNTY FAIR, JEFFERSON, IOWA, SEPTEMBER 17, 1924

Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
Mac	G	6	1480	2911	27½ ft.	Clyde Kinney
Jim	G	6	1480			

IOWA STATE FAIR PULLING CONTEST RECORDS, DES MOINES, IOWA, 1924

(Light weight pairs—less than 3,000 lbs.)

Place	Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
1st	Pearl	M	------	1500	2500	27½ ft.	Des Moines Ice & Fuel Co.
	Jess	M	------	1490	2600	25½ ft.	
2d	Wendells Glory	M	9	1400	2500	27½ ft.	Harry Harkins
	Wendells Ruth	M	9	1530	2600	16.9 ft.	
3d	Billy	G	13	1360	2250	27½ ft.	Merchants Transfer Co.
	Teck	G	6	1550	2500	4.8 ft.	

IOWA STATE FAIR PULLING CONTEST REPORTS, DES MOINES, IOWA, 1924

(Heavy weight pair—3,000 pounds and over)

Place	Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
1st	Pat	G	9	1695	3000	27½ ft.	Blue Line Transfer Co.
	Barney	G	8	1710	3100	12.6 ft.	
2d	King	G	6	1760	2750	27½ ft.	Merchants Transfer Co.
	Jim	G	8	1740	3000	10 ft.	
3d	Sam	G	7	1625	2750	27½ ft.	Des Moines Ice & Fuel Co.
	Morgan	G	6	1740	3000	2.9 ft.	
4th	Cap	G	10	1730	2500	27½ ft.	C. C. Taft Co.
	King	G	10	1890	2750	27 ft.	

HIGH TEST TEAMS WITH RECORD MADE IN CANADA (REGINA), 1924

Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
Barney	G	8	1910	3100	27½ ft.	Gibbs Bros.
Jumbo	G	8	1880			

RECORDS MADE IN CANADA

Name	Sex	Age	Wt.	Maximum pull exerted (Lbs.)	Length of pull	Owner
------	G	------	3660	3150	27½ ft.	R. B. McLeod, Saskatoon, Canada
------	G	------	------			
Jumbo	G	------	------	3300	27½ ft.	Gibbs Bros., Regina, Canada
Barney	G	------	3932			

TABLE IV—WINNERS IOWA STATE FAIR PULLING TESTS, 1925

Light Weight Pairs

Name	Sex	Age	Wt.	Breed	Maximum pull exerted (Lbs.)	Length of pull	Owner
Jim	G	7	1475	Grade Perch.	3200	23 ft.	Clyde Kinney,
Mack	G	7	1440	Grade Perch.	3100	27½ ft.	Bagley, Iowa
Frank	G	8	1480		3100	24.5 ft.	Des Moines Ice and Fuel
Prince	G	6	1470		3000	27.5 ft.	Co., Des Moines, Iowa
Pearl	M	12	1435	Grade Perch.	3100	19.25 ft.	Des Moines Ice and Fuel
Jess	M	12	1460	Grade Perch.	3000	27.5 ft.	Co., Des Moines, Iowa
Florence	M	11	1440	Shire	2925	19.33 ft.	John Donaghy,
Bess	M	11	1460	Shire	2700	27.5 ft.	Slater, Iowa
Babe	M	7	1460		2925	17.25 ft.	Merchants Transfer Co.,
Billy	G	13	1500		2700	27.5 ft.	Des Moines, Iowa
Dora	M	8	1390	Perch.	2925	6 ft.	W. J. Dawson & Sons,
Ted	G	10	1500	Grade Perch.	2700	27.5 ft.	Washta, Iowa
Queen	M	9	1415		2700	24.5 ft.	Cleon Bess,
Opal	M	9	1415		2500	27.5 ft.	Bagley, Iowa

Heavy Weight Pairs

Name	Sex	Age	Wt.	Breed	Maximum pull exerted (Lbs.)	Length of pull	Owner
Barney	G	9	1860		3425	27.5 ft.	Blue Line Transfer Co.,
Pat	G	10	1825				Des Moines, Iowa
Tom	G	7	1680		3400	24.5 ft.	Des Moines Ice and Fuel
Jim	G	6	1820		3200	27.5 ft.	Co., Des Moines, Iowa
Doc	G	10	1800	Grade Perch.	3200	25.8 ft.	Merchants Transfer Co.,
King	G	7	1890	Grade Perch.	3000	27.5 ft.	Des Moines, Iowa
Polly	M	7	1540	Grade Perch.	3000	24.5 ft.	C. E. Parmenter,
Ned	G	14	1580	Shire-Perch.	2500	27.5 ft.	Ankeny, Iowa
Captain	G	6	1855		3000	18.35 ft.	W. A. Rinehart,
Colonel	G	6	1930		2500	27.5 ft.	Palmyra, Mo.
Jim	G	9	1770		3000	13.5 ft.	Merchants Transfer Co.,
Bill	G	9	1700		2500	27.5 ft.	Des Moines, Iowa

RECORD MADE AT STORM LAKE FAIR, OCTOBER 10, 1925

Name	Sex	Age	Wt.	Breed	Maximum pull exerted (Lbs.)	Length of pull	Owner
Cap	G	10	3700		3475	27.5 ft.	Clarence Bugh,
King	G	11					Cherokee, Iowa

cause of a horse holding back or even quitting because they cannot breathe.

When collars are too long or too wide the point of draft may not come on the correct part of the shoulder and again a horse's efficiency is lowered. A poorly fitting collar is usually the cause of sore necks and shoulders, a condition which also greatly interferes with an animal's efficiency.

The value of good horsemanship has also been shown clearly in all contests. A poorly driven team invariably makes a poor showing. Examples of good driving, and what might be termed a complete understanding between driver and team, were shown in the 1925 Iowa State Fair contest. Clyde Kinney, driving his own team to a new record, understood the peculiarities of his team thoroly; neither driver nor team was ever excited and when Mr. Kinney told his team to go the pair settled into their collars and never faltered until they were told to stop. There was no shouting, no shaking of lines, or any disturbance of any kind. Mr. Kinney drove his horses with a tight line and had them under perfect control at all times.

The champion heavyweight team, owned by the Blue Line Transfer and driven by M. A. Miles, was also perfectly handled. When this team was attempting to set a new record several things happened that might have disturbed a team that was not carefully driven and handled by a competent teamster. On the first attempt the team broke a single tree and the cable which held the weights. Both horses were thrown to their knees but their driver quieted them in a short time and they were immediately re-hitched.

On their second attempt an iron evener was bent double and pulled the horses so closely together that they could not pull and they were stopped. In spite of these two mishaps, Mr. Miles brought his team back and on the third attempt established a new world's record by pulling 3,425 pounds. Horsemanship played an important part in establishing new records in this contest.

INTERPRETATION OF RESULTS

Since the term, "tractive pull," especially as applied to horses, is not familiar to the average person attending fairs and demonstrations, a word of explanation is given to show how big a load a given tractive pull would move. This will depend upon the rigidity of the road and wheel surfaces, grade, size, number and width of wheels, and type of axle. Also the tractive pull required to start a load is much greater than that required to keep it in motion. Assuming conditions similar to those in test reported in table II it is reasonable to conclude that for a dirt road the gross load equivalent would be about 25 times the tractive pull; for an asphalt pavement 42 times the tractive pull, and for a concrete pavement 130 times the tractive pull. Much more would be required for starting. This may be misleading when considered in connection with the results of some of the pulling contests because the record pulls have been made on turf or dirt track where the footing for horses is much better than can be secured on pavement. The result of the tests do, however, demonstrate the ability of well trained horses to meet emergencies which may be encountered in getting out of bad places.

The ability of horses to pull depends upon their strength, and the available footing. The ability of the driver, however, the disposition, and training of the horses are all important in getting them to put forth a maximum effort.

It is possible for a horse well trained to exert a tractive pull equal to his weight.

PART II.

STUDY OF THE HORSE AS A MOTOR

PRELIMINARY WORK

A preliminary trial was carried on for three weeks in the fall of 1922 with a pair of Percheron mares weighing approximately 1,800 and 1,900 pounds. These mares had been doing ordinary farm work and were seasoned workers at the time the trial began. The tractive load was started at 100 pounds per horse and gradually increased to 190 pounds tractive pull per horse or 380 pounds for the team. The team was driven first on bluegrass sod and later on a graveled road and traveled approximately 20 miles per day.

Both mares were in foal but the work did not seem to bother them until the smaller mare developed organic heart trouble and since she was a valuable brood mare it seemed advisable to discontinue the work for the year. The horses had not lost weight and looked to be in first-class condition.

EXPERIMENT—SUMMER 1923

The test was resumed May 15, 1923, and ended October 18, covering a period of 154 consecutive days. A new team of grade draft mares, weighing 1,475 and 1,625 pounds, were secured for this work. The team had been used in construction work, and were seasoned horses in good working condition but not fat. (Figs. 17 and 18).

EXPERIMENTAL PROCEDURE

The horses were watered at 5:30 a. m. and immediately fed grain and hay. They were then groomed and harnessed and left in their stalls until 6:45 when they were weighed individually and then hitched to the wagon and started on the road at 7:00 a. m. The tractive pull for the day was determined

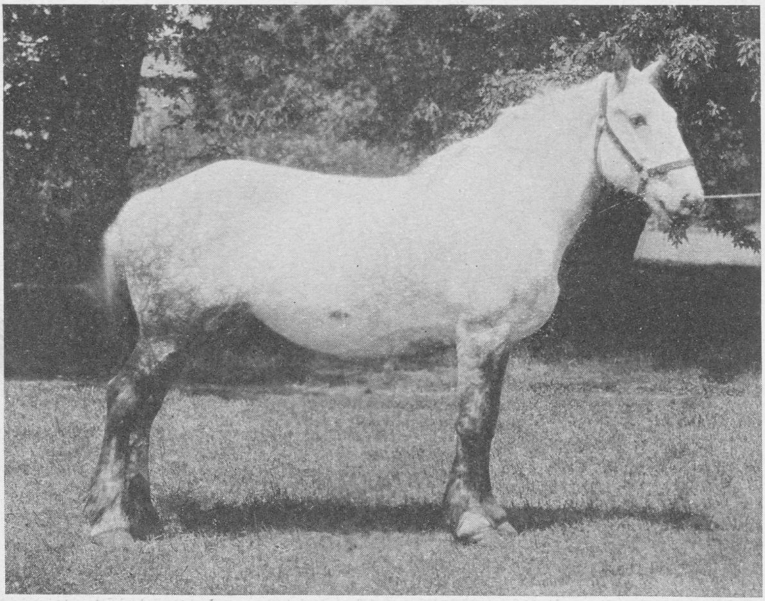

Fig. 17. Mable, age 7 years. Grade Percheron used in the experiment during the summer of 1923. Weight 1,625 pounds.

before starting and remained the same for the day unless some unforeseen circumstance necessitated a change.

The horses traveled 10 miles at the rate of $2\frac{1}{2}$ miles per hour. They were again weighed, watered and after resting a short time were fed grain. At 12:45 the team was watered, weighed and then hitched so that by 1 o'clock they were ready to start on the afternoon's work and covered 10 miles at the same rate as they traveled in the morning. The horses were rested for one minute at each quarter mile to correspond to stops made when plowing. The course covered was partly graveled and partly ordinary dirt road. During wet weather all the work was done on the graveled road but the same distance was covered.

The ration used was 50 per cent oats, 35 per cent shelled corn and 15 per cent wheat bran by weight along with timothy hay. The ration remained constant except on days when the horses did not work, then the grain allowance was cut in half. Each horse received a little over one pound of grain for each 100 pounds of live weight, with 25 to 30 pounds of timothy hay. This team had always been fed an excessive amount of hay and seemed to fret and worry if an abnormally

TABLE VI—INITIAL, FINAL AND AVERAGE DAILY WEIGHTS BY MONTHS.

	May					Mabel				
	Initial weight 1500—Final weight 1470					Initial weight 1625—Final weight 1650				
Month	A. M. wt.	Noon wt.	1 P. M. wt.	6 P. M. wt.	Daily shrink*	A. M. wt.	Noon wt.	1 P. M. wt.	6 P. M. wt.	Daily shrink*
May	1525.00	1510.83	1543.25	1509.23	15.77	1715.25	1690.00	1732.50	1695.92	19.33
June	1529.88	1480.29	1527.75	1491.73	38.15	1727.88	1672.94	1716.87	1683.00	44.88
July	1525.58	1484.04	1539.85	1489.07	36.51	1704.01	1638.33	1691.19	1647.03	56.98
August	1522.59	1471.60	1521.4	1485.86	36.73	1673.33	1617.80	1666.60	1631.20	42.13
Sept.	1503.21	1467.61	1494.09	1461.42	41.79	1670.00	1636.42	1662.27	1642.06	27.94
October	1484.47	1443.63	1486.00	1451.17	33.30	1664.73	1622.72	1665.00	1638.82	25.91

*Daily shrink obtained by subtracting 6 p. m. wt. from a. m. wt.

large amount was not allowed them each day. Barrel salt was fed ad lib.

Table VI is a tabulation of the average daily weights by months of each horse. It shows that during the early part of the experiment the horses gained in weight, and in spite

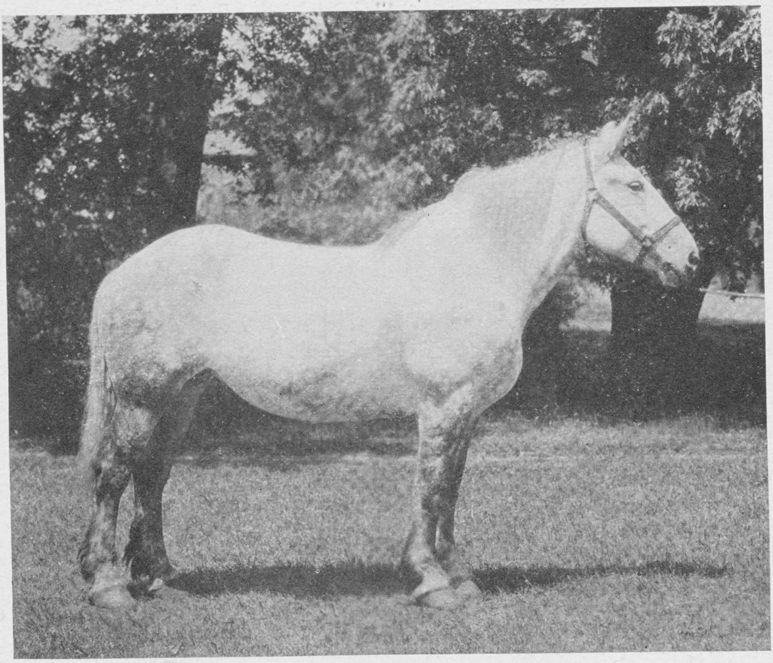

Fig. 18. May, age 8 years. Grade Percheron used with Mable in the experiment in 1923. Weight 1,465 pounds.

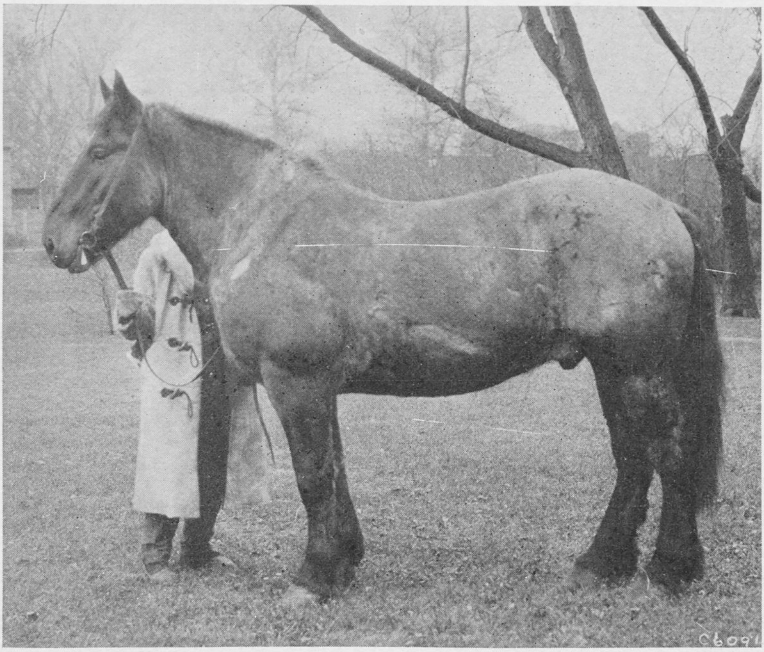

Fig. 19. Bob, age 4 years. Grade Belgian gelding used with John in the 1924 experiment. Weight 1,790 pounds.

of very hard work during the last month they weighed more at the end than they did at the beginning of the test. To find out what variations there would be in the daily weights of horses at work, four weights were taken daily.

Column five shows the average daily loss per horse, which varied from 15.77 to 56.98 pounds. The loss or shrink can be accounted for thru perspiration, respiration, urination and defecation, because after the horses had been watered and fed they regained their normal weights.

The average daily weights indicate that the work was not severe enough to cause a marked decrease in weight from month to month even tho the tractive pull and the actual work done per horse was greater each month.

The factor of weight alone may not, however, indicate accurately a horse's working capacity. A few hours or a day's rest may be time enough for horses to regain their former weight but this may not indicate their true condition.

It is practically impossible at present to determine the state of fatigue of an animal. Experienced horsemen may observe the general condition of an individual but they cannot determine the actual physical condition and know exactly if the horse is approaching a state of fatigue. In two years of experimental work where horses were pulling loads equivalent to a horse power or more for eight hours per day, day after day, they showed no outward signs of a fatigued condition; but they were, of course, tired at the end of the day.

They were, however, somewhat limited in their work by sore shoulders that persisted in spite of good care. The pull on the dynamometer wagon was constant and never varied regardless of whether the pull was up hill or down. The steady, constant pull for mile after mile, day after day, never allowed the shoulders to rest or cool off to any extent during work hours. Rest periods were observed but these did not compensate for the rest periods horses have when doing either farm or city work.

City teams move heavy loads but they usually deliver a load and come back empty which rests their shoulders or they travel over roads where the load may not require any pull but must be held back. This lifts the collars from the shoulders and allows them to cool and become dry. This makes it much easier to keep shoulders free from sores and in good working condition. Farm horses also are not worked

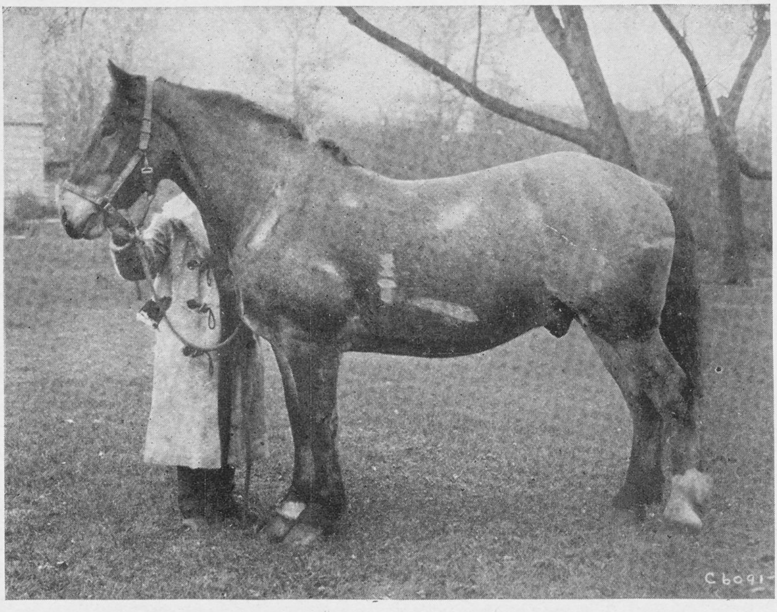

Fig. 20. John, age 9 years. Grade Belgian gelding of splendid type used in the 1924 experiment. Weight 1,800 pounds.

as constantly as these horses were. Rainy days and different kinds of work are not as apt to cause sore shoulders as the steady, constant pulling done in these experiments.

Sore shoulders, more than fatigue or loss of weight, limited the tractive pull of the teams in these experiments. The conformation of the shoulder, the way the collar fits and the character of the work may be the limiting factors in a horse's ability to work.

Data shown in the form of a chart gives the results for the years 1922, 1923 and 1924.

EXPERIMENT IN 1924

The third year's work was started May 2, 1924 and ended Dec. 6, 1924, or covered a period of 219 consecutive days. A new team of geldings weighing 1,760 and 1,790 pounds, respectively, were secured for this test. Bill, the near horse of the pair, was used during May and 16 days in June when he was replaced by John, a nine-year-old gelding weighing 1,800 pounds. (Figs. 19 and 20). These geldings had been doing ordinary farm work and were fairly well seasoned to start with, altho the farm work they had been doing was not as hard as that in the experiment proved to be.

No radical changes were made in the experimental procedure as outlined in the 1923 results except that only two weights were taken, one before the work began in the morn-

TABLE VII—INITIAL, FINAL AND AVERAGE DAILY WEIGHTS AND AVERAGE DAILY SHRINK BY MONTHS.

	*Bill and John			Bob		
	Initial weight 1760.00—1800.00			1790.00		
	A. M.	P. M.	Daily Loss	A. M.	P. M.	Daily Loss
May	1746.00	1738.70	7.30	1795.56	1789.45	6.11
June, Bill	1754.37	1745.50	8.87	1782.07	1757.51	24.56
John	1820.00	1785.43	34.57			
July	1785.48	1754.19	31.29	1779.03	1748.06	30.97
August	1801.61	1764.51	37.10	1809.68	1771.61	38.07
September	1813.00	1776.66	36.34	1851.66	1819.66	32.00
October	1812.26	1776.13	36.13	1871.61	1831.29	40.32
November	1794.00	1760.66	33.34	1860.00	1824.00	36.00
December**	1800.00	1767.50	32.50	1870.00	1836.25	33.75
Final weight	1800			1870		

*Bill used during May and 16 days in June.
**Experiment ended p. m. Dec. 6, 1924.

TABLE VIII—AVERAGE DAILY FEED BY MONTHS.

	Bob		John		Bill	
	Grain	Hay	Grain	Hay	Grain	Hay
May	12.83	13.40	------------	------------	11.83	13.23
June	10.88	16.0	14.50**	18.28	9.00*	16.67
July	16.70	17.80	16.87	17.80	------------	------------
August	19.22	17.93	18.84	17.84	------------	------------
September	23.50	18.90	23.50	18.90	------------	------------
October	25.22	20.00	25.22	20.00	------------	------------
November	24.03	19.66***	24.03	19.66***	------------	------------
December	22.33	20.00***	22.33	20.00***	------------	------------
Average for period	18.81	18.20	19.08	18.35	------------	------------

*Sixteen days.
**Fourteen days.
***Estimated.

ing and again at the close of the day, while in the year previous, weights were taken four times daily.

Table VII gives the initial, average daily weights by months and the final weights of each horse. This table also shows the daily shrink in weight due to work and the normal bodily functions. The first month the horses averaged a very small daily shrink but as the work increased this loss was greater, reaching a maximum of 40.32 pounds in the case of Bob during October.

The table shows further that while the horses varied somewhat in average daily weights by months, that the initial and final weights were practically the same, except that Bob had gained 80 pounds. This bears out the second year's results, showing that it was not difficult to maintain the weight of the horses even when they were doing work which for most of the time was equivalent to one horse power or more.

The rest periods were lengthened somewhat so that the horses might cool and rest their shoulders a longer time. Even with the increased rest periods the team used in 1924 covered the same distance in a shorter time than did the team in 1923. This pair traveled from two and one-half to three miles per hour (55 minutes travel, 5 minutes rest) for the daily 20 miles and did it day after day with a load that never varied regardless of grade or road surface, except as the load was changed by the teamster at the beginning of each day's work.

The ration used the third year was a mixture of 60 per cent oats, 30 per cent shelled corn, 10 per cent wheat bran by weight and timothy hay. On Sundays,[1] holidays and days when necessary repairs were being made on the wagon and the horses could not work, the grain ration was reduced about

(1. Duration of experiment, 219 days; Sundays 31; holidays 5; sickness 3 days.)

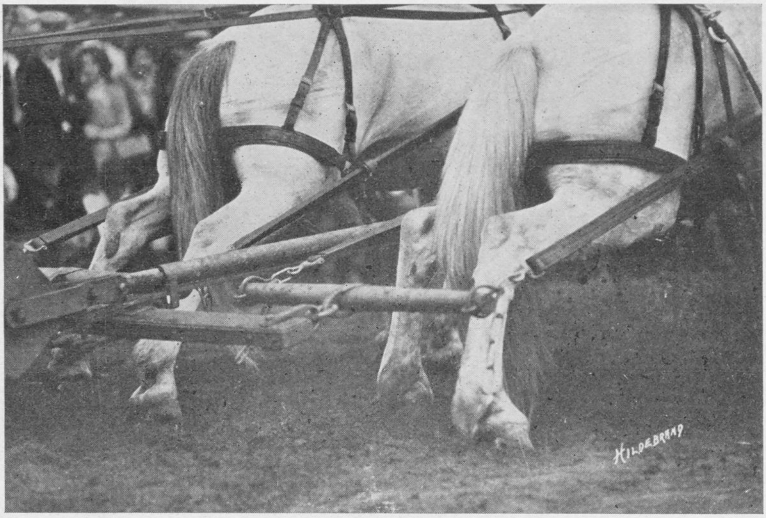

Fig. 21. This shows the tremendous strain on the hocks when the horses are pulling. This shows a pair of Bronchos weighing 2,305 pounds starting a load of 2,000 pounds.

one-half. A comparatively small amount of grain was fed at the beginning and this was increased as the work increased. Table VIII shows the average daily consumption of feed by months and the average for the entire experiment. The ration seemed adequate in every way because the horses maintained their weights satisfactorily and except on one occasion they were in good health.

Chart I shows the tractive pull per horse and the horse power hours developed by each horse. The tractive pull as shown by the dots varied from 100 to 200 pounds, or considering the time required and distance traveled, each horse developed from 2/3 to 1.42 horse power.

The horse power hours developed per day was calculated by multiplying the tractive pull by the total number of feet traveled per day while pulling the load. The product is the number of foot pounds of work performed per day. This product divided by 1,980,000 (the number of foot pounds equivalent to one horse power for one hour) gives the horse power hours developed per day.

The chart shows a number of days when the horses were not doing a full day's work. Except on days marked S or T (S indicating sickness or sore shoulders, and T indicating extreme heat or humidity), the shortened days were not due to the inability of the horses to work. During the summer of 1923, the plan called for daily work (except Sundays and holidays) regardless of weather. During early June rains were frequent, followed by days of high relative humidity and temperature (maximum humidity 73 and temperature 86). Continuing the work under these conditions resulted in both horses developing sore shoulders. It was deemed advisable to rest the horses and the work was discontinued for a week, from June 17 to 24.

During part of July and August 1924, more trouble with sore shoulders was encountered and because of this the work was lightened. This was done by requiring the team to travel five miles with a load and five miles without. They continued to cover 20 miles per day but the horse power hours developed per day per horse were thereby reduced. Work performed in this manner, however, corresponds to city hauling or drawing on the farm where a team pulls a load one way and draws the empty wagon the other.

The team was also used during this time for maximum pulling tests on the large dynamometer. These maximum pulls no doubt required a great deal of energy on the part of the horse but it was not possible to show on the chart exactly how much energy was expended in these pulls.

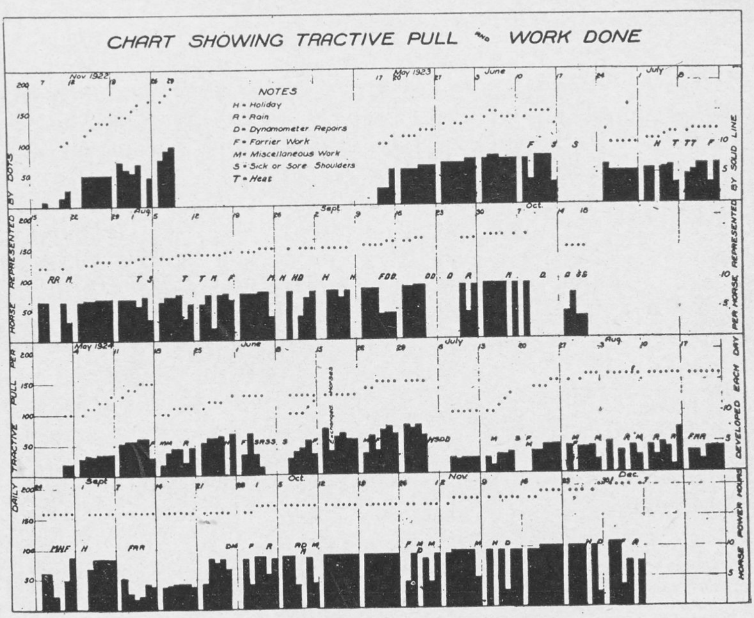

Chart I

Fig. 22. The sensational pair of Grade Percherons owned by Clyde Kinney of Bagley, Iowa. This team weighing 2,915 pounds pulled a load of 3,100 pounds and thus accomplished a feat heretofore considered impossible.

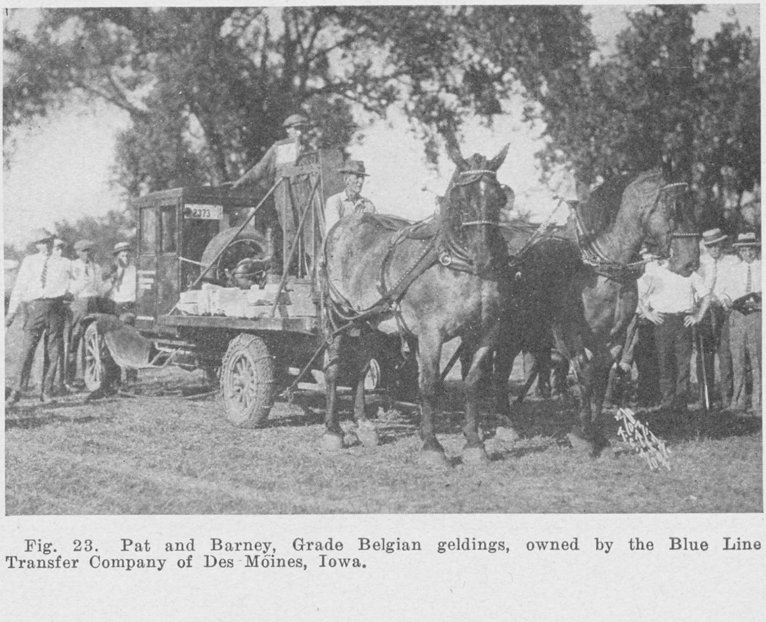

Fig. 23. Pat and Barney, Grade Belgian geldings, owned by the Blue Line Transfer Company of Des Moines, Iowa.

The chart marked "M" shows that the horses did not complete a full day's work but during these times they were being used on other work, such as drawing feed, hauling manure or making maximum pulling tests. It should not be considered that the horses could not have completed their regular work on these days but circumstances were such that it was necessary to transfer to the other work for a time even tho no credit could be given them for the horse power hours of work.

As a matter of fact, the only hours the horses actually lost

Fig. 24. Mac and Jim, world's record light weight pair in action. A well trained pair with the abundant nerve and stamina being perfectly driven by their owner.

were for shoeing, dynamometer repair work, rainy days and one week in 1923 when the team was rested because of sore shoulders.

SUMMARY

1. The experiments as outlined required a steady, constant pull and the load did not vary either going up or down the small hills. Work of this nature is different than city work or even field work. In the cities the load is usually pulled only one way, and the differences in the character of the soil in field work makes a great variation in the pull required on farm implements.

2. Two years' work has demonstrated clearly that it is possible for horses weighing from 1,500 to 1,900 pounds or over to pull continuously loads of 1 horse power or more for periods longer than one day. The work in the summer of 1923 covered 154 consecutive days and the 1924 experiment covered 219 consecutive days, including Sundays and holidays.

3. It is possible for a well trained horse to exert an overload of over 1,000 percent for a short time. No other type of motor can develop such an overload.

4. A pair of horses developed as high as 29.76 horse power in an official test.

5. The reserve strength of horses is of inestimable value in all kinds of work to users of horses. It is useful for drawing loads over uneven and un-uniform roads, in all kinds of field work where the soil varies a great deal and all kinds of work in the cities.

6. Daily observations of horses working during all kinds of summer weather indicate that humid days are much harder on them than dry, hot days.

7. The correct fitting of collars and the proper care of the horses' shoulders are essential if maximum work is to be obtained. Steady hard work in hot weather is very hard on their shoulders and it is difficult in spite of good care to always keep them in good condition.

8. If it is necessary to work horses hard during rainy weather, housings should be provided to keep the collars and shoulders as dry as possible. An excessive amount of moisture under the collar of a horse at work may cause a galling of the skin and if the horse continues to work, a raw sore is practically sure to develop.

9. Three years of experimental work have demonstrated clearly that it is possible for horses to exert a tractive effort of one-tenth to one-eighth of their own weight and travel a total of 20 miles per day without undue fatigue. Where the distance is shorter and the time required is less, a larger load can be handled.