

AD 701942

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DESIGN, DEVELOPMENT, AND TESTING OF
TIRES FOR 16 TON GOER VEHICLES

FINAL REPORT

CONTRACT NO. DA-33-019-ORD-3478
(Including Modification 1 - 7)

THE FIRESTONE TIRE & RUBBER COMPANY

AKRON, OHIO

This project was performed under the technical
supervision of Research & Engineering Directorate,
Army Tank-Automotive Command.

Cleveland Ordnance District Office
Ordnance Project No. TW-510
D/A Project No. 546-09-036

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November, 1963

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Abstract

AD _____ Accession _____
Firestone Tire and Rubber Co., Akron, Ohio
Design and Testing of 29.5-25 tires for
16 ton Goer Vehicle - T. J. Lonson, E. S. Sites
December, 1963 - pp - illus - tables

Contract No. DA-33-019-ORD-3478
D/A Project No. 546-09-036
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Earthmoving tires were specifically developed for use on the Goer vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service.

OBJECT

The object of the original contract dated 30 September 1960 was to design and develop 29.5-25 16 ply rating tubeless tires to provide optimum performance when used on the Goer vehicle. It was also desired to attain these goals while using the maximum feasible synthetic content.

Subsequent modifications (1-7) from June, 1961 through January, 1963 called for:

1. Non-destructive drum testing.
2. Temperature testing in continuous highway service.
3. Traction testing in various soils.
4. Durability testing on paved (40%) and secondary (40%) roads and off-highway terrain (20%).

Conclusions:

1. We found that it was possible to produce tires more suited to the requirements of the Goer vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud. The three designs developed are shown in figures 1-4.

Figure 1 - Super Ground Grip Goer

Figure 2 - Super Ground Grip Goer (Grooved)

Figure 3 - ND-CC Goer

2. Maximum synthetic content of the 29.5-25 SGG Goer was found to be 50% of the polymer used. The maximum synthetic content was determined by an evaluation of compound properties considering separation resistance and wear, cut, chip and tear resistance, as determined through the specific tests performed during the term of this contract and its modifications. However, certain inherent deficiencies from increasing synthetic (relative to natural rubber which is being replaced) in larger Off-The-Road type tires, should be recognized. These are:

A. Higher Heat Build-Up

To use synthetic in the tread of the tire, it was found necessary to incorporate a cooler-running, high-natural-rubber-content compound in the tread base under an all-synthetic tread cap compound, in order to lower the tire temperature in the critical separation area on top of the tire carcass.

B. Poor Crack or Cut Initiation and Growth

This deficiency manifested itself quite markedly during the durability testing. As a result of these tests, compound modifications were made in the all-synthetic tread cap stock to improve upon this property for future Goer tires.

C. Lower Resistance to Chip and Tear

Although the all-synthetic tread cap has been compounded to obtain the maximum cut, chip and tear resistance, without sacrificing other properties, there is an inherent lower resistance relative to natural rubber, for Off-The-Road type service, which compromises the overall performance of the tire. The exterior compounds of the tire (i.e. the tread and sidewall) have adequate protection against atmospheric deterioration and good low temperature

Firestone
Super Ground Grip Goer
Directional

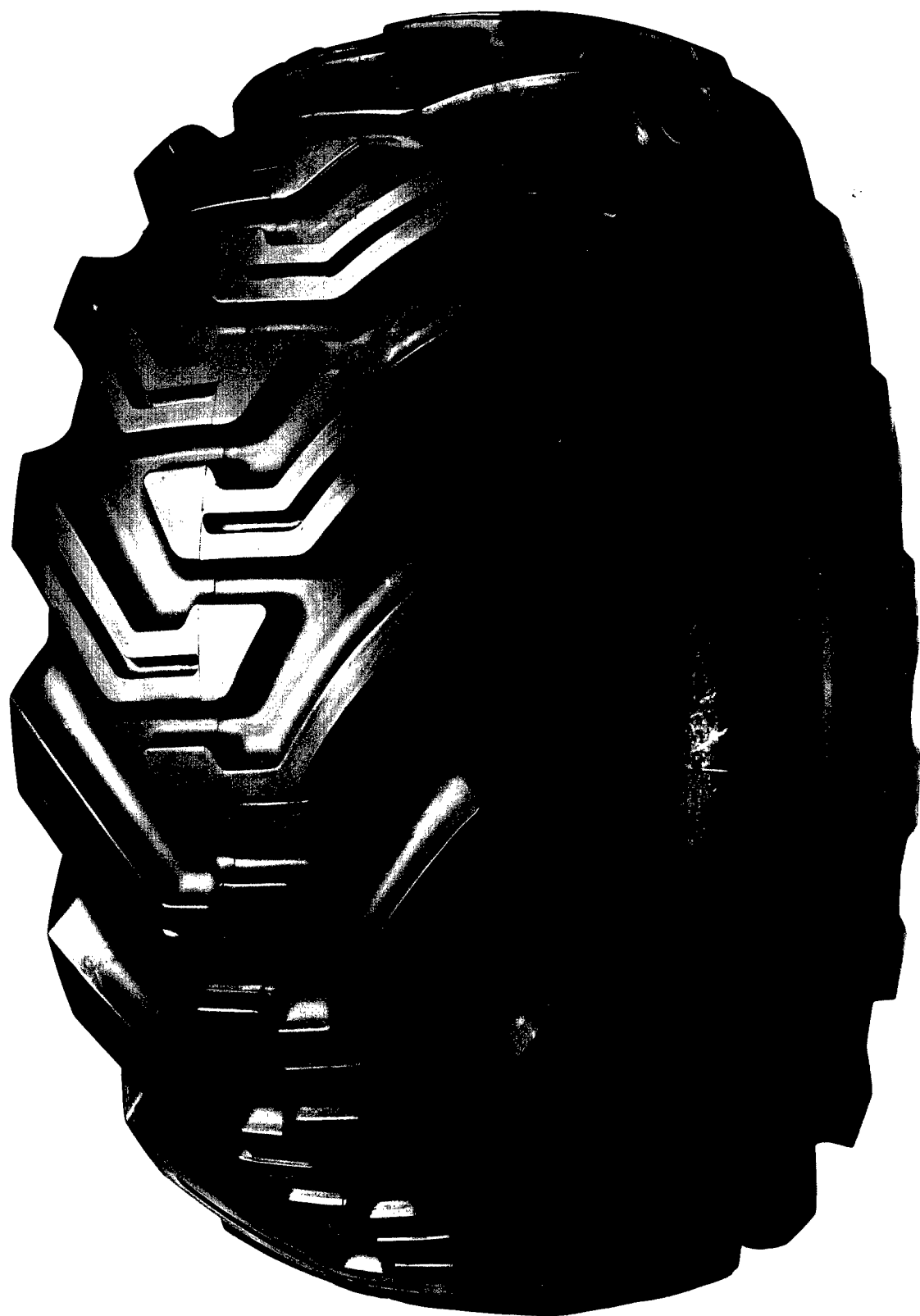
Figure 1



Firestone
Super Ground Grip Goer
(with grooves)

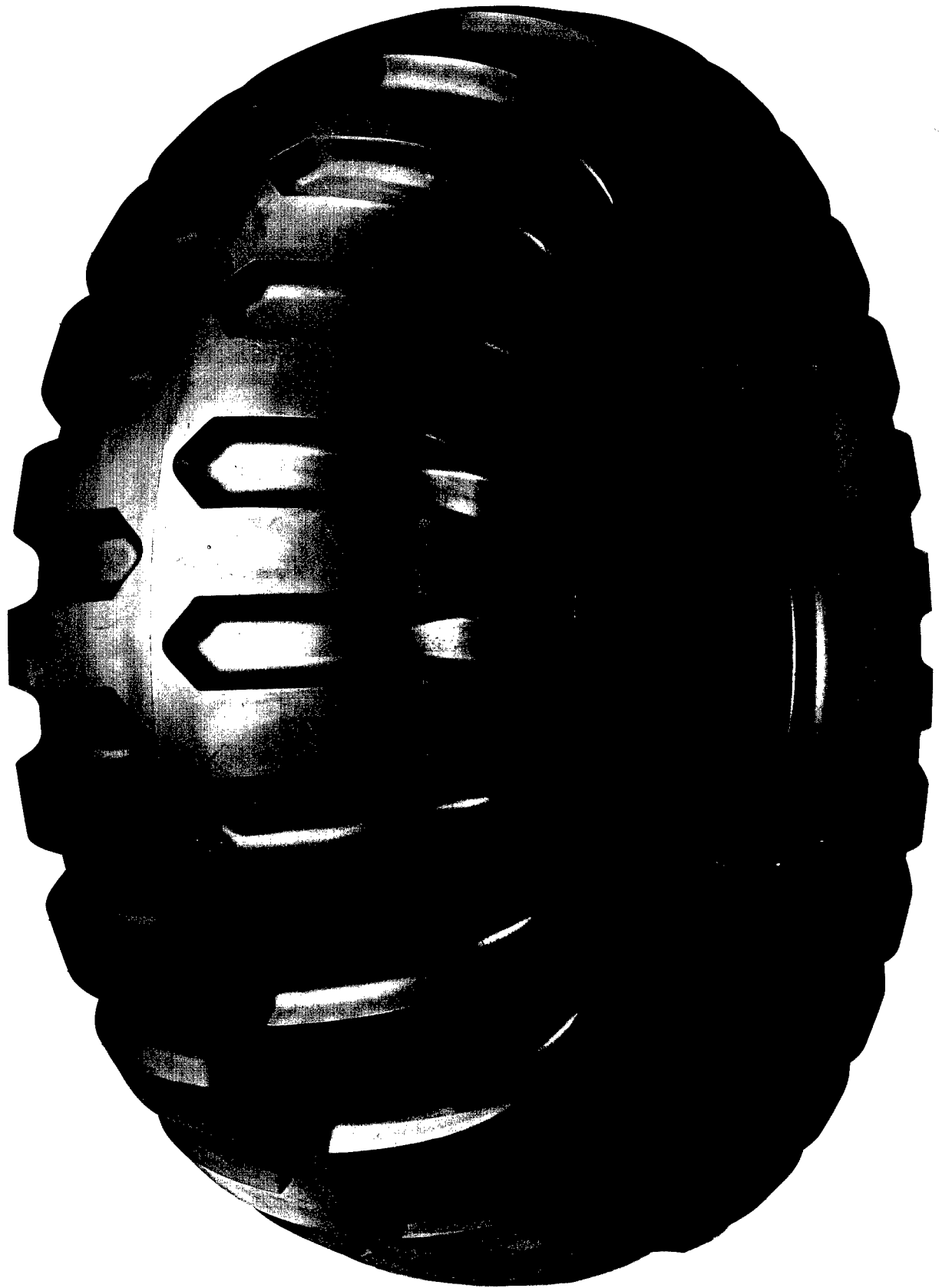
Directional

Figure 2



Firestone
ND-CC Goer
Non-directional

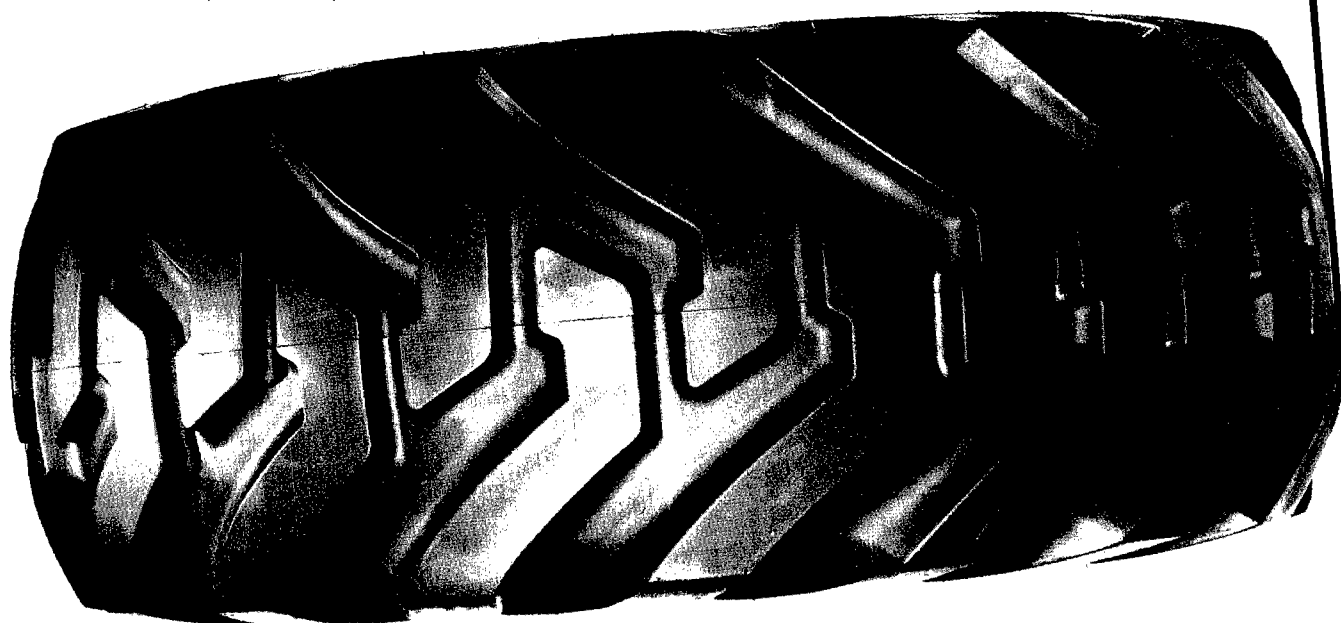
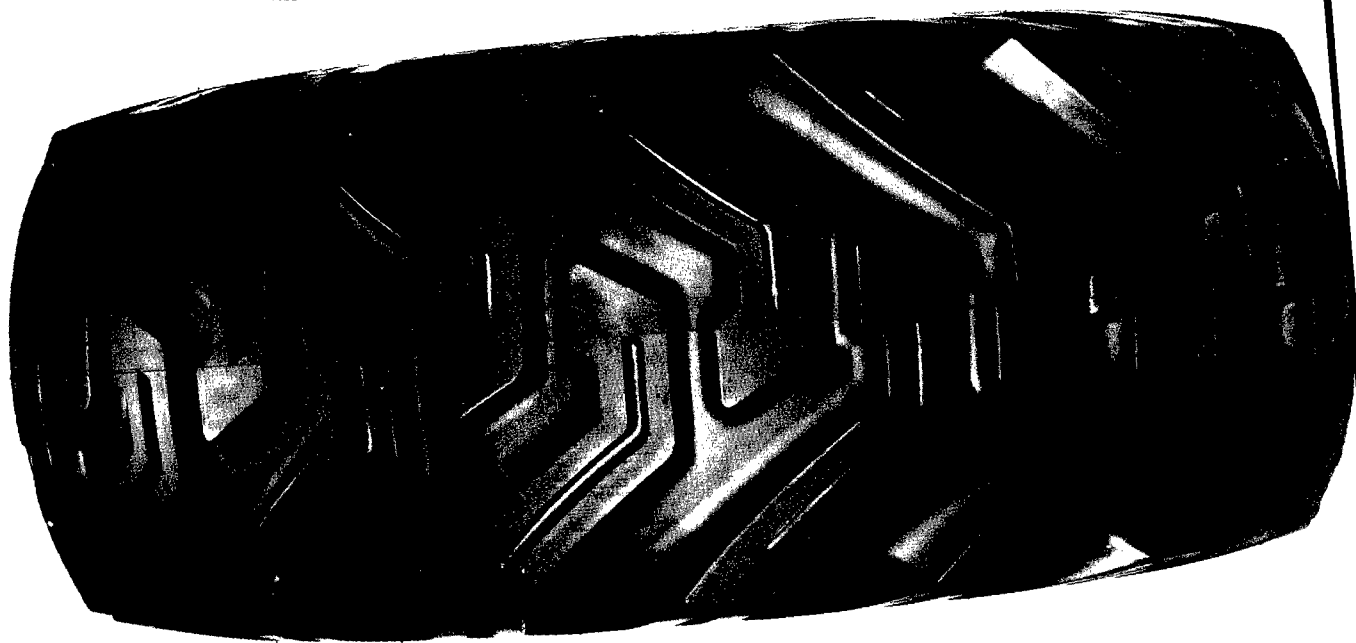
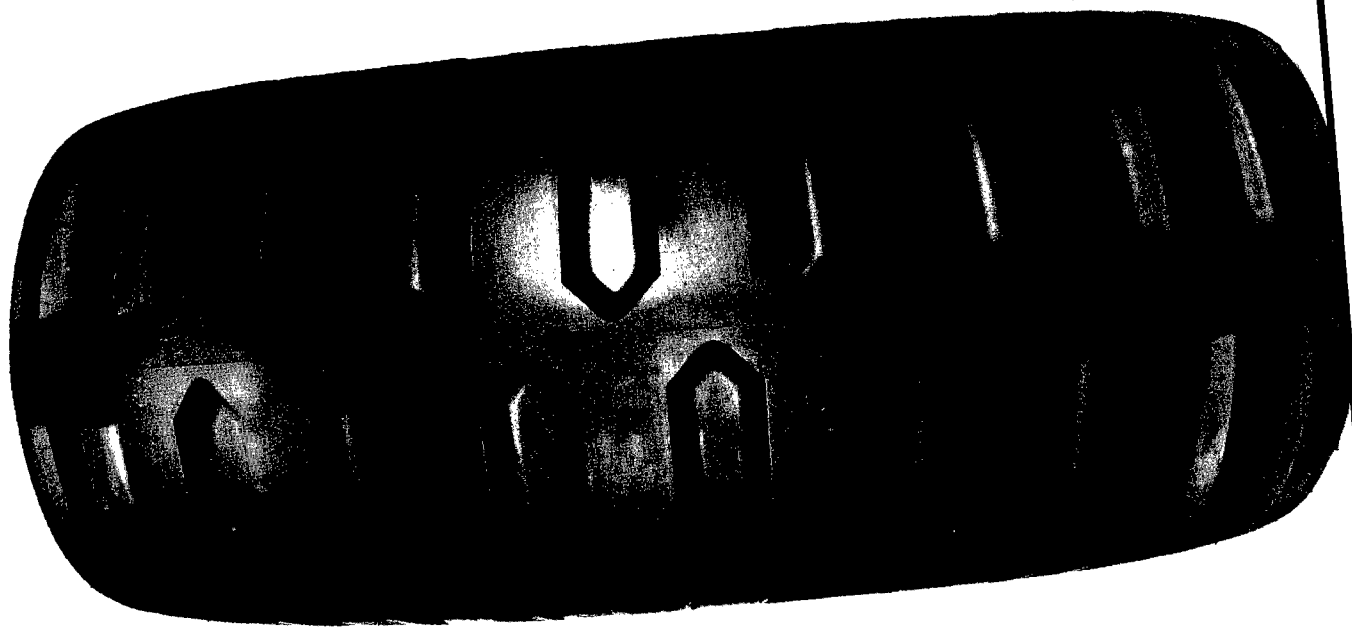
Figure 3



Head-on view of the three test designs
From left to right-

Super Ground Grip Goer
Super Ground Grip Goer (with grooves)
ND-CC Goer

Figure 4.



flexibility as a result of the particular blend of synthetic polymers used.

Use of the protective coatings described under Tire Compounding markedly enhances the tires' exterior compounds' resistance to atmospheric deterioration.

3. Of the three designs developed for this contract, the best design for optimum performance, as determined by these tests, was the Super Ground Grip Goer tire with the grooved tread bars. This was the only tire of the three which would operate at a sufficiently low temperature to allow use of the maximum synthetic rubber construction and still permit continuous highway operation. This design, with or without the tread grooves, is approximately three times as effective in deep mud as the ND-CC Goer design. The ND-CC tire was approximately 10 to 15% more effective for drawbar pull on non-compressible surfaces and compressible soil. There was little difference in the sand performance of any of these designs. Our selection of the grooved Super Ground Grip Goer tire as the optimum was based on the premise that the prime requirement of these tires was the ability to operate continuously in highway service and provide maximum performance in mud.
4. Shown below is a table which summarizes the information obtained from the durability phase of the testing. The significant factors are that no tires were removed due to any type of premature failure. Also, the tires with the synthetic tread had a wear rating double that of the natural rubber tires.

TABLE - DURABILITY TEST SUMMARY

TYPE	SGG GOER (GROOVED)	SGG GOER (GROOVED)	ND-CC GOER
Compounding	Natural Rubber	Synthetic Rubber	Natural Rubber
Average Test Miles Per Tire Sample	10,022	15,040	7,509
Reason for Removal	Worn Smooth	Worn Smooth	Test Terminated
Durability Rating	100	150	Not Available
Tread Wear, Average Miles/mil. (1)	6.1	12.2	16.3
Tread Wear Rating	100	200	267

- (1) See pp. 19-20 of Final Report, Durability Testing - Summary of Tire Tread Wear

It can be concluded from this testing that the Super Ground Grip Goer (grooved) tire with the natural rubber construction will not provide the desired 15,000 mile durability; however, through use of a synthetic construction, this level can be achieved. The ND-CC Goer design should provide approximately 20 to 25,000 miles with the natural rubber construction used, and could possibly double this figure by using the same synthetic compounds used in this test. It must be remembered that we are limited by the operating temperatures also.

Recommendations

1. Since no one design tested was clearly superior in all of the categories evaluated, it would seem that there is probably some design that would provide better overall performance than either of the three designs tested. It is our recommendation that additional testing be conducted to evaluate other design variations that would improve the mobility of the Goer vehicle.
2. This contract was limited to a tread design and compounding evaluation. It would also be beneficial to conduct tests in an attempt to evaluate the effects of various types of carcass constructions.
3. Use compound modifications to the all-synthetic tread cap compound referred to under conclusion #2 and under Tire Compounding, section B-1. These modifications were incorporated into the tires being fabricated for the European Troop Tests to be conducted in the spring of 1964.
4. Use tire protective Coating A referred to under Tire Compounding, section A-5. This coating has been used on all Goer tires manufactured by Firestone.
5. In view of the promising performance of the high-percentage-synthetic compounds in these tires, in service where natural rubber is normally used, continued compounding studies should be conducted to improve upon the overall performance characteristics of the high-synthetic-bearing compounds.

Background

Prior to this development contract, special tires were produced in existing commercial molds and supplied for use on the first four Goer vehicles. Design features of these tires were aimed primarily at maximum traction and continuous highway operation.

These tires performed fairly well, but a need was recognized for tires designed specifically for Goer vehicle-type service.

Subsequently, this contract called for production of four tires of each of three different designs. In addition, tires were to be produced with the maximum feasible synthetic content. In order to test these various characteristics, the following five tire specifications were issued and the corresponding tires produced:

<u>Serial</u>	<u>Type</u>	<u>No. Tires</u>	<u>% Synthetic</u>
K12500	SGG Goer	2	11%
K12600	SGG Goer	2	52%
K12700	SGG Goer with grooves	4	13%
K12800	ND-CC Goer	2	14%
K12900	ND-CC Goer	2	56%

Modification 1 dated 22 June 1961 called for one of each of these tires to be tested on an indoor laboratory drum to provide a temperature comparison.

Modification 3 dated 20 September added on-vehicle testing which would include an evaluation of these tires for continuous highway operation, mud, sand, drawbar pull, slopes, and maneuverability. These tests were subcontracted to Le-Tourneau-Westinghouse with ATAC approval. They conducted the highway temperature comparison and the mud tests but the drawbar pull tests in sand, non-compressible surface, and compressible soil were subcontracted by them to Nevada Automotive Test Center, Carson City, Nevada.

Modification No. 7 added a 20,000 mile durability test and twelve additional tires were supplied. Six of these were control tires in the Super Ground Grip Goer (with grooves) design with standard earthmover tire construction and compounding (natural rubber) features. The remaining six tires were the same except that the maximum possible synthetic rubber content was used.

In addition five tires in the ND-CC Goer design were purchased under contract number DA-20-089-ORD-40018. These tires were used as replacements for the durability test. Four of these tires attained 7500 miles before the 20,000 mile test limit was reached.

Mold Design and Tire Construction Development

The design of the tires for the 16 ton Goer vehicle requires consideration of the following criteria:

1. Gross Vehicle Weight - 64,000 Lbs.
4 Tires
58% of load on front axle
42% of load on rear axle
2. Speed - Maximum over 30 MPH
Cruise at 20 MPH
Water at 4 MPH
3. Roadability - Capable of long sustained hauls.
4. Traction - Maximum in mud.
5. Flotation - Good in all soils (mud and sand).
6. Minimum vehicle.
Ground Clearance - 30"
7. Ozone Resistance - Equivalent of standard military specification requirements.
8. Compounding - Maximum feasible synthetic content.
9. Durability - 25,000 miles.

From the above data, the 29.5-25 size was selected as the optimum tire for use on this vehicle. This will provide the load carrying capacity and ground clearance required, and this wide base profile will provide maximum flotation and traction.

After the size selection was finalized, it was necessary to arrive at the best possible tread configurations. It was originally decided to bring in one tire mold with three separate tread rings; however, upon consideration of factory production engineers, it was decided to fabricate two unicast molds rather than one. Although this increased the cost over the original estimate, the advantages provided both the contractor and the customer decisively outweighed the additional cost to the contractor.

The three tread designs selected were:

1. Super Ground Grip Goer (maximum traction) See figure 1
2. Super Ground Grip Goer with grooves (modified maximum traction). See figure 2.
3. ND-CC Goer. See figure 3

The Super Ground Grip Goer design was similar to our own commercially proven Super Ground Grip WB tire. The purpose of the tread grooves in the modified tire was to reduce the tire operating temperature. Prior experience indicated that this would reduce tire operating temperatures by approximately 15°F.

Design dimensions for the ND-CC Goer were based on Tire and Rim Association limits and design criteria in MIL-T-12459A for cross country type tires.

Shown below is an evaluation of the performance characteristics which we felt could be expected from these three designs:

	<u>Super Ground Grip Goer</u>	<u>Super Ground Grip Goer (with Grooves)</u>	<u>ND-CC Goer</u>
Directional	Yes	Yes	No
Mud Traction	Excellent	Excellent	Good
Sand	Good	Good	Good
Highway Roadability	Fair	Fair	Fair
High Speed	Good	Excellent	Good
Continuous Operation			
Wear Resistance	Good	Good	Good
Cut Resistance	Fair	Fair	Fair

In order to carry the required load and yet have the lightest possible construction, a 16 ply rating construction was chosen as the optimum. The load rating for this tire is 17,190 pounds at 25 psi inflation for intermittent operation and 14,520 pounds at 30 psi for continuous highway operation. The weight of these tires is approximately 800 pounds.

The carcass construction utilized 840/2 nylon with a tensile of 30 pounds per cord. These twelve tires were of twin bead construction, 14 actual plies, and two tread plies. They also had an under base of .45". All other features were standard production items with the exception of the compounding.

TIRE COMPOUNDING

A. ORIGINAL CONTRACT

1. BASIC REQUIREMENTS FOR GOER TIRE COMPOUNDS

1. COMPOUND STOCK WITH MAXIMUM SYNTHETIC CONTENT
2. COMPOUND STOCKS FOR PROTECTION AGAINST ATMOSPHERIC
DETERIORATION
3. COMPOUND PROTECTIVE COATING TO COMPARE WITH (2)
4. COMPOUND: BEST COMPROMISE BETWEEN COOL RUNNING TIRE AND
CUT, CHIP AND WEAR RESISTANT TREAD AND SIDEWALL

2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

TIRE IDENTIFICATION

29.5-25 16 PLY TUBELESS

	<u>SERIAL IDENTIFICATION</u>	<u>COMPOUND LINE-UP</u>	<u>% OF POLYMER AS SYNTHETIC</u>	<u>NO. OF TIRES</u>
SUPER GROUND GRIP GOER MAXIMUM TRACTION DESIGN	K12500	I	11	2
	K12600	II	52	2
SUPER GROUND GRIP GOER MODIFIED MAXIMUM TRACTION DESIGN	K12700	I	13	4
ND-CC GOER DESIGN	K12800	I	14	2
	K12900	III	56	2

2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

	COMPOUND DESCRIPTION		
	<u>LINE UP I</u>	<u>LINE UP II</u>	<u>LINE UP III</u>
Tire Serial Identification	K12500, K12700, K12800	K12600	K12900
Tread	NR	Isoprene	Oil Extended FR-S
Sidewall	$\frac{1}{2}$ Neoprene- $\frac{1}{2}$ NR	$\frac{1}{2}$ Isoprene- $\frac{1}{2}$ NR	Oil Extended FR-S
Outer Body	NR	NR	$\frac{1}{4}$ Isoprene- $\frac{3}{4}$ NR
Inner Body	$\frac{1}{4}$ Diene - $\frac{3}{4}$ NR	Same as Line Up I	Same as Line Up I
Innerliner	7/10 Chlorobutyl-3/10 NR	"	"
Bead Insulation	FRS	"	"
Other Bead Compounds	NR	"	"

3. COMPOUND DESIGN

COMPOUND LINE UP I

Compound Line Up I with 11 to 14% of the polymer as synthetic (depending on weight distribution of tire components) is the least deviation from standard Off-The-Road Tire Compounding.

This Line Up features an all natural rubber tread with superior cut and tear resistance. The tread is specially compounded for cool running and resistance to atmospheric deterioration.

The sidewall is compounded from a polymer blend of 50% Neoprene and 50% natural rubber, and is extremely resistant to atmospheric deterioration.

The outer body is compounded from all natural rubber. It is cool running and furnishes maximum tear and heat resistance.

25% of the polymer as Diene and 75% natural rubber is the feature of the inner body. It is cool running and heat resistant.

The innerliner is compounded with 70% of the polymer as chlorobutyl and 30% natural rubber. Excellent heat resistance and impermeability to air are its features. One-half as much air is transmitted at 176°F and 75 psi through this type innerliner than through an all natural rubber innerliner.

COMPOUND LINE UP II

Compound Line Up II with 52% of the polymer as synthetic is a greater departure from standard compounding. Its tread polymer is 100% Isoprene specially compounded for best compromise between cool running and resistance to wear, tear and atmospheric deterioration.

The sidewall, compounded from 50% Isoprene and 50% natural rubber, is tear, cut and atmospheric deterioration resistant.

The same compound features as Line Up I are used in the remainder of the tire.

COMPOUND LINE UP III

Compound Line Up III, with 56% of the polymer as synthetic, features tread and sidewall compounds with all of the polymer as oil extended FRS, specially compounded for resistance to atmospheric deterioration.

The tread and sidewall are also compounded for cool running and cut and tear resistance.

Isoprene as 25% and natural rubber as 75% of the polymer is the feature

of the outer body. The outer body is compounded for cool running, and heat and tear resistance.

The remaining compounds are the same as Line Up II and III.

4. COMPOUND PROPERTIES

TREAD

Compound Line Up:	I	II	III
Tire Identification Serial:	K12500, K12700 K12800	K12600	K12900
Formulation:	100 NR	100 Isoprene	131 FR-S 123

Normal (70°F) Stress-Strain

Tensile, psi	4175	3025	3075
300% Modulus, psi	1750	1625	825
Elongation, %	540	480	675

Tensile @ 275°F

Tensile, psi	1100	625	700
Elongation, %	320	210	340

Normal (70°F) Tensile After 2 Days @ 212°F

Tensile, psi	2250	1275	2675
Elongation, %	250	185	465

Firestone Flexometer

Running Temp., °F	226	240	275
Deflection, %	15.3	16.7	20.7
Shore "A" Hardness	64	63	62

Ring Tear

Normal-70°F, lb/in	800	500	525
-212°F, lb/in	300	200	275

Brittle Point

ASTM D746-57T, °F	-63	-60	-45
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4. COMPOUND PROPERTIES

SIDEWALL

Compound Line Up:	I	II	III
Tire Identification Serial:	K12500, K12700, K12800	K12600	K12900
Formulation:	50 NR	50 NR	131 FR-S 123
	50 Neoprene	50 Isoprene	

Normal (70°F) Stress-Strain

Tensile, psi	3175	3725	3000
300% Modulus, psi	900	975	500
Elongation, %	640	635	765

Tensile @ 275°F.

Tensile, psi	700	700	400
Elongation, %	350	360	270

Normal (70°F) Tensile After 2 Days @ 212°F

Tensile, psi	1975	1025	2575
Elongation, %	405	265	570

Firestone Flexometer

Running Temp., °F	203	201	246
Deflection, %	26.7	20.0	24.7
Shore "A" Hardness	50	57	57

Ring Tear

Normal-70°F, lb/in	325	575	400
-212°F, lb/in	100	225	175

Brittle Point

ASTM D746-57T, °F	-71	-53	-45
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4. COMPOUND PROPERTIES

BODY

Compound Line Up:	I	II	III	I,II,III
Formulation:	<u>Outer Body</u>	<u>Outer Body</u>	<u>Outer Body</u>	<u>Inner Body</u>
	100 NR	100 NR	75 NR	75 NR
			25 Isoprene	25 Diene

Normal (70°F) Stress-Strain

Tensile, psi	4125	4100	3975	2900
300% Modulus, psi	1200	925	875	800
Elongation, %	600	670	685	580

Tensile @ 275°F.

Tensile, psi	1250	1250	1025	475
Elongation, %	520	630	540	220

Normal (70°F) Tensile After 2 Days @ 212°F

Tensile, psi	2050	1675	1925	1525
Elongation, %	375	390	425	405

Firestone Flexometer

Running Temp., °F	189	184	188	132
Deflection, %	23.3	24.7	26.0	20.7
Shore "A" Hardness	52	51	49	54

Ring Tear

Normal-70°F, 1b/in	550	850	550	200
-212°F, 1b/in	300	350	325	125

Brittle Point

ASTM D746-57T, °F	-69	-67	-63	-66
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4. COMPOUND PROPERTIES

REMAINDER OF COMPOUNDS

Innerliner, Bead Insulation, Bead Cover, Bead Filler, Chafer and Abrasion Gum Strip compounds are all standard Firestone compounds.

5. PROTECTION FROM ATMOSPHERIC DETERIORATION

COMPOUND PROTECTION

Tread and sidewall compounds feature standard Firestone Off-The-Road antiozonants for maximum resistance to atmospheric deterioration.

The oil extended FR-S tread and sidewall, and the Neoprene/natural rubber sidewall are superior to the Standard Military Control for accelerated weathering in the Firestone Weatherometer.

The natural rubber and Isoprene treads, and the natural rubber/Isoprene sidewall, while somewhat inferior to the Standard Military Control for accelerated conditions, are expected to be well protected for normal operations.

Comparisons of tread and sidewall compounds and the Standard Military Control were made in the Firestone Weatherometer under the following conditions:

1. 60 parts per 100 million of Ozone - 40 hrs. exposure-static - 100°F. - pre-aged 3 days at 158°F - 12½% elongation
2. Same as above except dynamic (10 min. flex - 50 min. static per hour) and strips not pre-aged
3. Same as (1) above except exposure at 40°F.

Photographs of results are on the following pages.

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER -
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F

TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F
AGED 3 DAYS AT 158°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F

AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

6. PROTECTION FROM ATMOSPHERIC DETERIORATION

PROTECTIVE COATINGS

From previous experience and studies during the period of this contract, the following two coatings were selected as the most practical.

- A. Firestone protective coating based on N, N'-dioctyl-p-phenylene diamine.
- B. Firestone protective coating based on Hypalon.

Coating A protects against atmospheric deterioration by depositing a layer of antiozonant which is absorbed into the surface of the tire.

Coating B protects against atmospheric deterioration by depositing a tough, clinging, elastic, protective film on the surface of the tire.

These coatings are very effective, but have the deficiency typical of coatings in that severe weathering occurs where the film is broken or not continuous, as shown in the photographs.

Comparisons of accelerated weathering, in the Firestone Weatherometer, of these coatings on the natural rubber tread (Line Up I), the Isoprene tread (Line Up II), and the natural rubber/Isoprene sidewall (Line Up II) are shown in the attached photographs.

Test conditions are the same as those described under Compound Protection.

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC 100°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F

TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F
AGED 3 DAYS AT 158°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F

AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F
AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

B. DURABILITY TESTS

1. COMPOUND MODIFICATIONS

Prior to fabricating the 29.5-25, 16 ply SGG GOER tires for the Durability Tests, a review of the original three compound line ups' performance pointed out the need for some reconsiderations of the compound design. In order to improve the tires' durability characteristics from an overall compromise between cool running and cut, chip and wear resistance, a number of modifications were made in the compounding design. An overall compromise, utilizing the maximum synthetic content felt to be permissible, was chosen for one set of tires (K25500 Serial Identification), to be tested against control tires (K25300 Serial Identification) using standard Firestone Off-The-Road compounds (approximately all natural rubber).

The final selection of compounds featured a three-piece tread construction (details below) to obtain the best compromise between cool running for separation resistance and cut, chip, tear and wear resistance, while incorporating synthetic into a portion of tread.

The final compound combination resulted in a synthetic content of 50% of the polymer used.

Tread Cap or Veneer: An all-synthetic compound with a polymer blend of 50% Diene and 50% oil-extended FRS. The synthetic portion of the tread is confined to essentially only the lugs of the design to keep its higher heat build-up characteristics (relative to natural rubber) away from the critical separation area of the tire on top of the tire carcass. The use of Diene imparts added wear and cracking resistance over the previous all oil-extended FRS tread compound (original contract work, Compound Line Up III), plus giving an improvement in low temperature flexibility.

Tread Base: An intermediate layer of a compound with a 75% natural rubber-25% Isoprene polymer blend, compounded to provide the best compromise between cool running and wear, cut, chip and tear resistance. The use of a predominantly natural rubber compound between the tread cap and carcass permits the use of the all-synthetic tread cap with no loss in separation resistance.

Tread Cushion: A separation-resistant layer compound lying between the tread base and tire carcass. This compound contains a polymer blend of 75% natural rubber and 25% Isoprene and is compounded for the best cool running features with the minimum sacrifice in wear, cut, chip and tear resistance. This compound in combination with the tread cap and tread base constitute the three-piece tread construction for the best overall compromise of tire compound properties.

Outer Body: Same as Tread Cushion.

Inner Body: Compounded for cool running and heat resistance, the Inner Body features a polymer blend of 75% natural rubber and 25% Isoprene.

Innerliner: Compounded with a polymer blend of 58% chlorobutyl, 24% natural rubber, and 18% Diene, this Innerliner features improved low temperature flexibility (due addition of Diene), over previous compound used in original contract tires, in addition to properties mentioned previously.

Remainder of Compounds:

Sidewall - Firestone standard Military Truck tire compound.

Others - Firestone standard Off-The-Road compounds.

Coatings - Firestone Coating A referred to under original contract compounding.

2. COMPOUND PROPERTIES

	<u>TREAD CAP</u>	<u>TREAD BASE</u>	<u>TREAD CUSHION</u>	<u>INNER BODY</u>	<u>INNERLINER</u>
<u>Normal (70°F) Stress-Strain</u>					
Tensile, psi	2850	3600	3675	3675	1275
300% Modulus, psi	650	1000	725	675	600
Elongation, %	710	590	645	610	560
<u>Tensile @ 275°F</u>					
Tensile, psi	650	825	725	525	-
Elongation, %	290	425	450	495	-
<u>Normal (70°F) Tensile After *Days @ 212°F</u>					
Tensile, psi	2475	1725	1275	1525	1175
Elongation, %	420	370	335	410	480
<u>Firestone Flexometer</u>					
Running Temp., °F	288	192	184	138	236
Deflection, %	18.7	12.7	26.0	24.7	24.7
Shore "A" Hardness	64	58	52	51	53
<u>Ring Tear</u>					
Normal-70°F, lb/in	525	300	350	575	-
-212°F. lb/in	300	150	150	225	-
<u>Brittle Point</u>					
ASTM D746-57T, °F.	-78	-54	-56	-59	-60

*Aging 6 days at 212°F. for Innerliner
2 days at 212°F. for All Others

3. TEST RESULTS

GENERAL CONSIDERATIONS

In view of the satisfactory performance of the previously mentioned three-piece tread construction for durability and the synthetic tread cap for wear in the Durability Tests, it was decided to use this compounding construction on the 29.5-25 16 Ply Rating SGG GOER tire manufactured for European Troop Tests. However, due to the synthetic's inherent weakness for crack growth, which evidenced itself quite prominently during the Durability Tests, modification of the synthetic tread cap stock was necessary.

TREAD COMPOUND MODIFICATIONS

The synthetic tread cap compound was modified in line with other Firestone compounding practices and experience to improve the compound's crack initiation and growth resistance. These modifications reduced the compound's ability to meet the Standard Military Ozone requirements; however, it is felt that the compound's resistance to atmospheric deterioration, especially with the protective coating used, is adequate. In general the compound's properties are similar to those of the tread cap compound listed under Durability Tests. The improvement in crack initiation and crack growth can be seen from the following data:

Firestone Groove Flexing Machine

	<u>Previous Compound</u>	<u>Modified Compound</u>	<u>Per Cent Improvement</u>
Crack Initiation (Minutes to Crk)	250	510	104
Crack Growth (Inches/ Hour)	.258	.110	.174

29.5-25 GOER TIRE DRUM TEMPERATURE
COMPARISON

Equipment: 70.5" diameter steel drum powered by Allis Chalmers 100 H.P.
AC Electric motor - 440 volts 495 RPM.

Brown Temperature Recorder and Copper-Constantan Thermocouples.

Test Features:

<u>Serial</u>	<u>Features</u>	
	<u>Design</u>	<u>Compounding</u>
K12500	Super Ground Grip Goer	11% Synthetic
K12600	Super Ground Grip Goer	52% Synthetic
K12700	Super Ground Grip Goer (With Grooves)	13% Synthetic
K12800	ND-CC Goer	14% Synthetic
K12900	ND-CC Goer	56% Synthetic

Test Conditions:

Load - 18,500 flat plate load
Speed - 17.1 MPH
Inflation - 40 psi
Ambient Temperature - 68°F

Test Results:

<u>Serial</u>	<u>Tread Temperature</u>			<u>Contained Miles Air Temp.</u>	<u>Run</u>	<u>Final Hot Inflation</u>
	<u>Center</u>	<u>Mid Point</u>	<u>Shoulder(Hot Spot)</u>			
K12500-2	179	197	208	144	150	48
K12600-1	201	221	229	149	150	50
K12700-4	177	191	196	145	150	49
K12800-2	196	206	222	147	150	50
K12900-2	227	230	240	142	113	47

Conclusions:

- Using the Super Ground Grip Goer as a control (K12500) for a running temperature comparison of these three designs, we see that the Super Ground Grip Goer (with grooves) is 12° cooler running and the ND-CC Goer is 14° hotter running than this control.
- There are two comparisons of the effect of synthetic content on running temperature:
 - K12500 (11%) vs. K12600 (52%)
(208°) (229°) +21°

B. K12800 (14%) vs. K12900 (56%)
(222°) (240°) +18°

This shows that the higher synthetic content is 18-21° hotter than the same tire with the lower synthetic content.

NOTE: These drum temperatures can not be construed as indicative of actual operating temperatures under these same conditions. Only a comparison of one vs. another can be made.

29.5-25 GOER TIRE
ON-VEHICLE TEMPERATURE COMPARISON
CONTINUOUS HIGHWAY SERVICE

Discussion

These on-vehicle temperature tests provide a comparison of the three designs (Super Ground Grip Goer, Super Ground Grip Goer with grooves, and ND-CC Goer) and also a comparison of high synthetic content (52 - 56%) vs. low synthetic content (11 - 14%).

All tires were tested on the same XM438 Goer Tanker with a gross vehicle weight of 69,800 lbs.

All tests were conducted on a 3-1/8 mile loop of highway which was part of the A.A.S.H.O. road test at Ottawa, Illinois. The duration of each test run was determined by the equilibrium point. When the temperatures leveled off, the tests were terminated. The tests were conducted 11-15, September 1961.

Test Features:

<u>Serial</u>	<u>Features</u>	
	<u>Design</u>	<u>Compounding</u>
K12500	Super Ground Grip Goer	11% Synthetic
K12600	Super Ground Grip Goer	52% Synthetic
K12700	Super Ground Grip Goer (With Grooves)	13% Synthetic
K12800	ND-CC Goer	14% Synthetic
K12900	ND-CC Goer	56% Synthetic

Test Conditions:

Load 69,800 lbs. G.V.W.

Inflation 40 psi drive, 30 psi trail

Speed 29 MPH Average.

Test Results (All Temperatures Corrected to 68° Ambient)

Inflation Actual Maximum

<u>Type</u>	<u>Serial</u>	<u>Position</u>	<u>Cold</u>	<u>Hot</u>	<u>Ambient</u>	<u>Temp. (Corr.)</u>	<u>Hours Run</u>
Super Ground Grip Goer	K12500-1	RF	40	52	65°	241°	4.7
Super Ground Grip Goer	K12600-1	LF	40	51	65°	272°	4.7
Super Ground Grip Goer	K12500-2	LR	30	40	65°	234°	4.7
Super Ground Grip Goer	K12600-2	RR	30	40	65°	239°	4.7
Super Ground Grip Goer (With Grooves)	K12700-2	RF	40	51	62°	217°	5.7
Super Ground Grip Goer (With Grooves)	K12700-1	LF	40	50	62°	219°	5.7
Super Ground Grip Goer (With Grooves)	K12700-3	LR	30	41	62°	213°	5.7
Super Ground Grip Goer (With Grooves)	K12700-4	RR	30	41	62°	206°	5.7
ND-CC Goer	K12800-1	RF	40	54	63°	233°	4.5
ND-CC Goer	K12900-1	LF	40	54	63°	255°	4.5
ND-CC Goer	K12800-2	LR	30	43	63°	208°	4.5
ND-CC Goer	K12900-2	RR	30	43	63°	236°	4.5

Conclusions

1. The effect of design on running temperature can be readily determined since one tire of each design was run under the same conditions using the Super Ground Grip Goer (K12500) as a control:

<u>Type</u>	<u>Serial</u>	<u>Position</u>	<u>Maximum Temperature</u>	
SGG Goer	K12500-1	RF	241°	Par
SGG Goer (With Grooves)	K12700-2	RF	217°	-24°
ND-CC Goer	K12800-1	RF	233°	- 8°
SGG Goer	K12500-2	LR	234°	Par
SGG Goer (With Grooves)	K12700-3	LR	213°	-21°
ND-CC Goer	K12800-2	LR	208°	-26°

These differences might be attributed to variations in the individual tires such as base gauge, etc.

2. The effect of synthetic content on tire operating temperature can also be determined. Four direct comparisons are available.

<u>Serial</u>	<u>% Synthetic</u>	<u>Position</u>	<u>Maximum Temperature</u>	
K12500-1	11%	RF	241°	+31°
K12600-1	52%	LF	272°	
K12500-2	11%	LR	234°	+ 5°
K12600-2	52%	RR	239°	
K12800-1	14%	RF	233°	+22°.
K12900-1	56%	LF	255°	
K12800-2	14%	LR	208°	+28°
K12900-2	56%	RR	236°	

Ave. Difference +22°

3. These tests determined that at inflation of 40 psi, drive and 30 psi, trail, the Super Ground Grip Goer tires (with grooves - K12700) should operate safely in continuous service at speeds under 30 MPH and at an ambient temperature of 68°.

We use 250°F as a critical temperature, and as an ambient temperature correction factor, we use 1/2°F tire temperature change for each 1°F. ambient change. It can be seen from these temperatures that at higher ambient temperatures all of the other designs would be marginal. Since it is desirable to use as high a synthetic content as possible, the Super Ground Grip Goer tire (with grooves) is the only one capable of continuous highway operation at high ambient temperatures when produced with the high synthetic construction.

TRACTION TEST SUMMARY

SAND, COMPRESSIBLE SOIL, AND NON-COMPRESSIBLE SURFACE

Discussion: The data and resulting conclusions shown in this summary have been abstracted from:

Final Report
Phase I
Project 20-1-102

Traction Ability of Various 29.5-25 Goer Tires in Sand, in a Compressible Soil, and on a Non-Compressible Surface.

This report was prepared by Nevada Automotive Test Center, Carson City, Nevada for Le-Tourneau Westinghouse Company in September, 1962.

OBJECT

The object of this test program was to evaluate the tractive ability of the following test tire groups (each featuring a difference in tread design) in sand, in compressible soil and on non-compressible surface.

- Group A: Firestone Ground Grip (Control Tires),
16 PR Directional Design, 29.5-25.
Serial numbers K-4300-9 and K-4300-14.
- Group B: Firestone ND-CC Goer, 16 PR
29.5-25.
Serial numbers K-12900-2 and K-12900-1.
- Group C: Firestone Super Ground Grip Goer, 16 PR,
Grooved Lug, 29.5-25.
Serial numbers K-21700-4 and K-12700-3.
- Group D: Firestone Super Ground Grip Goer, 16 PR,
Solid Lug, 29.5-25.
Serial numbers K12500-1 and K-12600-1.

CONCLUSIONS

SAND

In prepared sand simulating the loose "blow" sand common to the lee side of beach and desert dunes the initial desirable inflation pressure increments of 40, 30 and 20 PSI were predictably high for vehicle operation in the type of sand available at the test site. 20 PSI was found to be the maximum test pressure to which the tires could be inflated to permit movement of the test vehicle from highway to the sand course over a sand road traversable by jeep and pickup.

With maximum sand tire inflation pressure established at 20 PSI, 16 and 12 PSI were arbitrarily selected as the lower increments at which data would be generated.

Little significant difference in performance existed between these tires at 20, 16 and 12 PSI.

The 12 PSI inflation pressure would not be practical for any of these tires due to the severe traction buckle which appeared at this low pressure. Two of the eight tires tested experienced slippage between tire and rim.

The sand gradeability of the 64,000 lb. Goer vehicle equipped with Conventionally designed tires on all four drive wheels is calculated to be as follows:

Tire Group Inflation, Press.	A			B			C			D		
	20	16	12	20	16	12	20	16	12	20	16	12
Gradeability, %	25	30	34	24	29	34	(1)	29	32	27	29	32
Gradeability Rating as compared with Control Group A	100	100	100	96	97	100	(1)	97	94	108	97	94
Travel Efficiency Rating as compared with Control	100	100	100	95	103	96	(1)	103	101	100	104	103

(1) Could not negotiate sand course with drawbar load.

COMPRESSIBLE SOIL WITH GROUND COVER

As opposed to sand, tires in compressible soil continue to develop progressively more drawbar as travel efficiency diminishes (increased wheel spin). This being the case, comparative performance in terms of drawbar must be judged at comparable travel efficiency points. For specific comparisons see SUMMARY OF TEST RESULTS, Tractive Ability, Compressible Soil with Ground Cover. Of the experimental tires, the ND-CC Goer design, Group B, provided maximum drawbar pull under these conditions.

CONCLUSIONS (CONTINUED)

NON-COMPRESSIBLE SURFACE

Under these conditions, the Super Ground Grip Goer, Group D, provided the maximum drawbar pull of any of the experimental designs.

SUMMARY OF TEST RESULTS

Tire Group	Tractive Ability, Sand											
	A			B			C			D		
	20	16	12	20	16	12	20	16	12	20	16	12
Inflation Press. PSI	8.5	10.3	11.5	8.3	9.8	11.5	(1)	9.9	10.9	9.2	9.8	11.0
Maximum Drawbar, Lbs.	100	100	100	98	95	100		96	95	108	95	96
Rating												
% Travel Efficiency	78	77	77	74	79	74	(1)	79	78	78	80	79
Rating	100	100	100	95	103	96		103	101	100	104	103
Est. Max. Goer Gradeability, % (4 Wheel Drive)	25	30	34	24	29	34	(1)	29	32	27	29	32
Rating	100	100	100	96	97	100		97	94	108	97	94
Max. Calc. Goer Gradeability, % 64000 lb. GVW (2 Wh.Dr.)	13	15	18	13	15	18	(1)	15	17	14	15	17
Rating	100	100	100	100	94	100		94	94	108	94	94
Tire to Rim Slippage	No	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No
Traction Buckle	None	Sli.	Sev.	None	Sli.	Sev.	None	Med.	Sev.	None	Sli.	Sev.
Air Loss from Buckle	No	No	Yes	No	No	No	No	No	No	No	No	No
Steering Response and Cornering Roll (Tire)	Good	Good	Fair	Good	Good	Poor	Good	Good	Poor	Good	Good	Fair
Rim Contact with Sidewall	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Hard Surface Measurement												
Flange to Road, Inches												
Unloaded	19.5			21.3				21.5		19.6		
Loaded	12.9	11.5	10.0	14.3	13.0	9.9	15.5	14.4	12.8	14.1	12.9	10.5
% Deflection	34	41	49	33	39	54	28	33	40	28	34	46
Tire Mounting Ease without Hydraulic Tool Assist and with Hand Tools only (2 men)												
(1) Immobilizer.	Good			Fair				Poor			Poor	

SUMMARY OF TEST RESULTS

Tractive Ability, Compressible Soil with Ground Cover

	% T.E.	40 PSI			30 PSI			20 PSI		
		90	75	60	90	75	60	90	75	60
A Firestone Ground Grip WB (Control Tires) 16 PR	Drawbar Rating	9000 100	16200 100	19300 100	10800 100	16600 100	18700 100	11300 100	16300 100	18400 100
	Est. Grade. (4 Wh. Dr.)	26	48	57	32	49	55	33	48	54
	Calc. Grade. (2 Wh. Dr.)	14	25	30	17	26	29	18	25	29
B Firestone NDCC Goer Mil. 16 PR	Drawbar Rating	11100 123	18000 111	19900 103	11600 107	17600 106	19700 105	9200 81	15700 96	18800 102
	Est. Grade. (4 Wh. Dr.)	33	53	59	34	52	58	27	46	55
	Calc. Grade. (2 Wh. Dr.)	17	28	31	18	27	31	14	25	29
F Firestone Super Ground Grip Goer, 16 PR Grooved Lug	Drawbar Rating	9200 102	14800 91	18200 94	8300 77	14000 84	17900 96	8700 77	14500 89	18100 98
	Est. Grade. (4 Wh. Dr.)	27	44	54	24	41	53	26	43	53
	Calc. Grade. (2 Wh. Dr.)	14	23	28	13	22	28	14	23	28
G Firestone Super Ground Grip Goer, 16 PR Solid Lug	Drawbar Rating	10600 117	15800 98	18200 94	9700 90	15700 95	18100 97	8000 71	15500 95	18000 98
	Est. Grade. (4 Wh. Dr.)	31	46	54	29	46	53	24	46	53
	Calc. Grade. (2 Wh. Dr.)	17	25	28	15	24	28	12	24	28

SUMMARY OF TEST RESULTS (Continued)

<u>Tractive Ability, Compressible Soil with Ground Cover</u>				
<u>Averaged Drawbar Values (at 90, 75 and 60% Travel Efficiency) Rated Against Group A.</u>				
<u>Group</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
Infl. Press., 40 PSI	14800	16300	14100	14900
Rating	100	110	95	101
30 PSI	15400	16300	13400	14500
Rating	100	106	87	94
20 PSI	15300	14600	13800	13800
Rating	100	95	90	90

SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Non-Compressible Surface (Continued)

	% T.E.	40 PSI			30 PSI			20 PSI		
		90	75	60	90	75	60	90	75	60
A										
Firestone Ground Grip WB (Control Tires) 16 PR	Drawbar	18000	21300	21900	16500	21200	21700	7800	19000	20400
	Rating	100	100	100	100	100	100	100	100	100
	Est. Grade. (4 Wh. Dr.)	53	63	64	49	62	64	23	56	60
	Calc. Grade (2 Wh. Dr.)	28	33	34	26	33	34	12	30	32
B										
Firestone NDCC Goer 16 PR	Drawbar	12700	22100	24300	7700	17400	23200	8400	18700	22400
	Rating	71	104	110	47	82	107	107	98	110
	Est. Grade. (4 Wh. Dr.)	37	65	71	23	51	68	25	55	66
	Calc. Grade. (2 Wh. Dr.)	20	35	38	12	27	36	13	29	35
C										
Firestone Super Ground Grip Goer 16 PR, Grooved Lug	Drawbar	9300	19100	24300	7500	15900	22900	7500	16300	21900
	Rating	52	90	110	45	75	106	96	86	107
	Est. Grade. (4 Wh. Dr.)	27	56	71	22	47	67	22	48	62
	Calc. Grade. (2 Wh. Dr.)	15	30	38	12	25	36	12	25	34
D										
Firestone Super Ground Grip Goer, 16 PR, Solid Lug	Drawbar	14400	20600	21500	14300	20900	22100	14300	20600	21800
	Rating	80	97	98	87	99	102	183	108	107
	Est. Grade. (4 Wh. Dr.)	42	61	63	42	61	65	42	61	64
	Calc. Grade. (2 Wh. Dr.)	23	32	34	23	33	35	23	32	34

SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Non-Compressible Surface

Averaged Drawbar Values (at 90, 75 and 60% Travel Efficiency)
Rated Against Group A.

<u>Group</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
Infl. Press., 40 PSI	20400	19700	17600	18800
Rating	100	97	86	92
30 PSI	19800	16100	15400	19100
Rating	100	81	78	96
20 PSI	15700	16500	15200	18900
Rating	100	105	97	120

FINAL REPORT

DURABILITY TEST OF GOER TIRES
Phase III

Project 20-1-110

July 1963

Prepared For
LeTourneau-Westinghouse Company
Under Test Directive 224 Revised

Prepared By:

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Walter H. Statton
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Approved By:

Henry C. Hodges

Henry C. Hodges
President

Nevada Automotive Test Center
Carson City, Nevada

A Division of Hodges Transportation Inc.

FINAL REPORT

Project 20-1-110

Upper Photograph

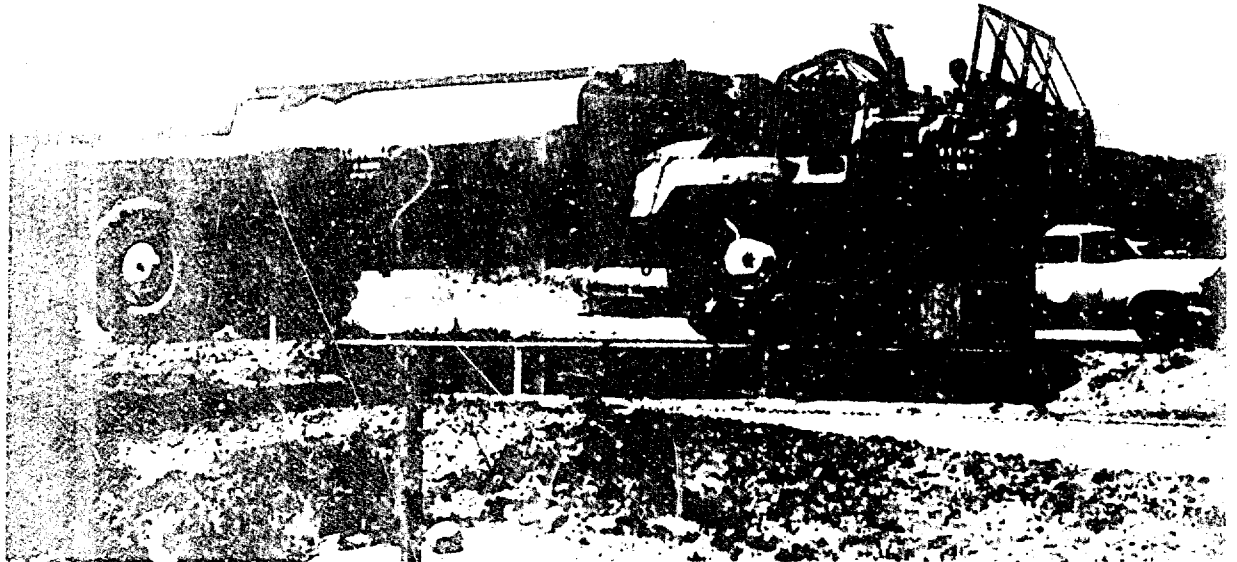
M 4382 Fuel Tank Truck being Weighed Prior
to "Ride" Evaluation

Lower Photograph

Three (3) Commercial Model "C" Tournapull
Vehicles Used In Tread Wear and Durability Test

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FINAL REPORT

Project 20-1-110

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FINAL REPORT

Project 20-1-110

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APPENDICES A AND B	Under Separate Cover

HISTORY

In August 1962 the Nevada Automotive Test Center, A Division of Hodges Transportation Inc., conducted an Engineering Study (Project 20-1-102) of the influence of tire tread design and carcass construction on the tractive efficiency of 29.5 - 25 tires applicable to unsprung four wheel vehicles such as the Model "C" Tourmapull and the ATAC "Goer".

In February 1963 two experimental tire groups and one control (Standard "Goer" 29.5 - 25) tire group were applied to three commercial Model "C" Tourmapull "test bed" vehicles for the purpose of establishing the comparative durability and tread wear performance of these tires when subjected to semi-continuous operation over paved highways, "washboard" secondary roads and cross-country trails.

OBJECT

The three tire test groups selected for this durability and tread wear study featured significant differences and the test program was set up to segregate the effect of these differences in terms of tire durability and tread wear:

Tire Group A, the standard 29.5 - 25 directional tread "Goer" tires, featured 16 ply conventional construction and natural rubber tread.

Tire Group B, the experimental 29.5 - 25 non-directional tread tires, featured radial ply construction.

Tire Group C, the experimental 29.5 - 25 directional tread tires, featured 16 ply conventional construction and synthetic rubber tread.

Two additional tire groups were available for durability and tread wear testing (Groups D and E) should premature failures develop in the original test tire groups.

Tire Group D, the experimental 29.5 - 25 non-directional tread tires, featured 16 ply conventional construction.

Tire Group E, the experimental 29.5 - 25 directional tread tires, featured radial ply construction.

One additional group of non-directional radial ply construction tires (Group F) with the same features as Group B was available for engineering investigation.

TEST PLAN

The tread wear and durability test plan established a requirement for the following:

A maximum of 20,000 vehicle miles per tire test group divided into 8,000 miles of pavement operation, 8,000 miles of secondary road operation and 4,000 miles of cross-country trail operation.

Front tire loads of approximately 19,400 lbs. per tire and rear tire loads of 16,000 lbs. per tire simulating the tire loads of the ATAC "Goer" fuel tank truck, XM 438E2.

Measurements of tread wear and tire deterioration each 2,500 miles of operation.

Rotation of test tires from vehicle to vehicle each measurement period to equate vehicle "test bed" differences.

Test speeds averaging 25 MPH on pavement, 25 MPH on secondary roads and 8 MPH over cross-country trails to be maintained commensurate with driver and vehicle safety.

Tire inflation at the maximum level permitted by cross-country terrain conditions in terms of driver and vehicle fatigue limits at the minimum average speed requirement of 8 MPH.

Tire temperatures on the pavement course.

Driver observations of vehicle "ride" and performance as influenced by tire reaction.

The specific test plan and procedures are set forth in detail in TEST PROGRAM of this report.

CONCLUSIONS

The following conclusions may be drawn from the data generated under the specific conditions of this test program as summarized in TEST RESULTS.

Tire Tread Wear

Regardless of tread design, tires of radial ply construction (Groups B and E) provide a significantly lower tread wear rate than tires of conventional construction (Groups A, C and D). Group B was 14% worn compared with A-79%, C-35% and D-32% worn at equal mileage.

With like tire construction, non-directional tread tires (Groups B and D) provide a lower tread wear rate than directional tread tires (Groups A, C and E).

The synthetic directional tread conventional construction tires (Group C) provide a significantly lower tread wear rate than the natural rubber directional tread conventional construction tires (Group A).

On the Model "C" Tournapull "test beds" rear tire wear rate exceeded front tire wear rate; however, in terms of irregular wear the non-directional design is not sensitive to axle position, whereas the directional design is sensitive.

Directional tread conventional construction tires (Group A) exhibit almost 100% higher lug pressure on the ground than do the non-directional tread radial ply tires (Group B) which increases unit rate of wear.

Tire Durability

The synthetic directional tread conventional construction tires (Group C) developed substantially greater tread cracking than the natural rubber tread tires (Group A) of the same construction.

Conventional construction tires (Groups A and C) are significantly more durable than the radial ply construction tires (Group B) experiencing no carcass failures of the original eight test samples, whereas the radial ply construction experienced three carcass failures and one tread separation of the original four test samples and one carcass failure of the three replacement tires subjected to test.

The relative durability of the two additional tire groups cannot be assessed as the accumulated test miles authorized for a tread wear comparison of these groups (Groups D and E) were respectively 7,500 and 2,500 miles which were not adequate for durability comparison.

CONCLUSIONS (Contd.)

Tire Temperatures

The non-directional radial ply tires (Group B) under normal conditions of pavement test operation ran at a slightly lower mean temperature (198°F) than the Groups A and C directional conventional tires (202°F).

The non-directional conventional tires (Group D) under normal conditions of pavement test operation ran significantly cooler (210°F) than the Group E directional radial ply tires (237°F); however, while the operating conditions were equivalent during the time these temperatures were recorded the accumulated group tire mileages were not (Group D-7,500 miles, Group E-2,500 miles).

In the pavement operation established for this test (8 hours continuous) tire Groups A, B, C and D will not generate temperatures in excess of 235°F providing all tires are normal, i.e., no separations or traumatic frictional generators.

Rolling Resistance

The directional conventional tires (Groups A and C) and the non-directional radial ply tires (Group B) were analyzed in terms of their relative influence on vehicle fuel consumption. A comparison of the fuel consumed by the three test vehicles applied to each tire group for an equal number of miles represents a rate of fuel consumption chargeable to each tire group without regard for vehicle differences. The foregoing disregards many possible variables but a trend was established from these data which showed a 6% improvement in the rate of fuel consumption attributable to the non-directional radial ply tires (Group B) when compared with the directional conventional tires (Group A) and an 8% improvement when compared with the directional conventional tires (Group C).

CONCLUSIONS (Contd.)

Instrumented "Ride" Study

Compared with the Model "C" Tournapull, the "Goer" Tanker at rated load provides significantly better "ride" characteristics on rough pavement and secondary road surfaces regardless of the influence of the tires.

In cross-country over natural obstacles the vehicle reaction is sharply sensitive to tire reaction which permits the equating of vehicle differences by tire selection, i.e., the "Goer" equipped with radial ply tires (Group F) is equally as acceptable as the Model "C" Tournapull equipped with conventional directional tires (Group A), whereas when these tires are reversed in vehicle assignment the two vehicles are equally "ride" deficient.

On pavement and secondary road surfaces the "ride" of the "Goer" Tanker equipped with non-directional radial ply tires (Group F) is essentially insensitive to limited tire pressure change, whereas the Model "C" Tournapull "ride" is extremely sensitive. Equipped with conventional directional tires (Group A) both vehicles exhibit a slight pressure change sensitivity.

By comparison the "ride" characteristics of the non-directional conventional tires (Group D) are considered deficient in any "rough" area on any surface when mounted on the Model "C" Tournapull. The non-directional radial ply tires (Group E) provide the best over-all Model "C" Tournapull "ride" on pavement and secondary road surfaces and better cross-country "ride" than the non-directional radial ply (Group F). Assuming the influence of the "Goer" on the cross-country "ride" of the Group F tires would hold true for the directional radial ply Group E tires, the Group E tires would provide a significantly better over-all "Goer" "ride" than any other tire group tested.

Using the Model "C" Tournapull as a "test bed" and under the eleven different test conditions in the "Ride" Study to which all tire groups were subjected the directional conventional (Group A) tires exceeded the human fatigue limit⁽¹⁾ under five conditions and the vehicle fatigue limit⁽²⁾ under two conditions; the non-directional radial ply tires (Group F) exceeded the human fatigue limit under six conditions and the vehicle fatigue limit under three conditions; on the same comparative basis, the non-directional conventional ply tires (Group D) exceeded the human fatigue limit seven times and vehicle fatigue limit four times; and the directional radial ply tires (Group E) exceeded the human fatigue limit four times and the vehicle fatigue limit three times.

- (1) Acceptable "Human" Continuous Fatigue Limit of .89 (Ride Index), as Interpreted from Goldman's "Unpleasant" Limit.
- (2) Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index), as Interpreted from Goldman's "Intolerable" Limit.

CONCLUSIONS (Contd.)

Instrumented "Ride" Study (Contd.)

Using the "Goer" Tanker as a "test bed" and under the same conditions applied to the Model "C" Tournapull "test bed" the directional conventional (Group A) tires exceeded the human fatigue limit three times and the vehicle fatigue limit once, whereas the non-directional radial ply (Group F) tires exceeded the human and vehicle fatigue limit only once under the single cross-country condition.

Instrumented Shallow Mud Traction Study

Only the directional conventional (Group A) tires and the non-directional radial ply (Group F) tires were subjected to this Mud Traction Study and the following conclusions may be drawn from their performance.

The directional conventional (Group A) tires depend upon increased ground pressure for increased traction, whereas the non-directional radial ply (Group F) tires depend upon decreased ground pressure for increased traction.

At their optimum inflation pressure within the range investigated (15-55 psig) the maximum traction of the two groups being compared were equal at 55 psig for the Group A tires and 15 psig for the Group F tires.

The pressure print profile of the two groups at their maximum traction indicated a single high pressure contact in the crown of the Group A tires and two high pressure contacts at the shoulders of the Group F tires.

At their maximum traction the static lug ground pressure of the Group A tires is 228 PSI and the Group F tires is 48 PSI which influences tire flotation characteristics.

The vehicle ground clearance is reduced by the inflation pressure reduction required by the Group F tires.

In shallow mud the tread void areas of the Group A tires are cleared of mud buildup at 15 psig inflation, whereas the Group A are substantially loaded. At 55 psig inflation the Group A tread void areas are cleared of mud buildup and the Group F tires are substantially loaded.

CONCLUSIONS (Contd.)

Instrumented Shallow Mud Traction Study (Contd.)

CONSIDERATIONS FOR IMPROVING "GOER" MUD TRACTION

To achieve acceptable mobility, the "Goer" vehicle equipped with non-directional radial ply tires should not be operated in shallow mud with more than 25 psig front tire inflation pressure and 20 psig rear tire inflation pressure, whereas the directional conventional (Group A) tires should not be operated with less than 45 psig front tire inflation pressure and 40 psig rear tire inflation pressure.

To achieve acceptable soil trafficability (mud track pass factor) neither Group A nor Group F should be inflated to more than 25 psig.

These data indicate that in deep mud the directional tread (Group A) tires at 35, 45 or 55 psig inflation can negotiate a more severe condition in forward travel than in reverse; consequently, consideration should be given to what inflation pressure might be used to extricate the vehicle when forward travel is no longer possible.

Serious consideration should be given to evaluating the deep mud potential of:

1. Non-directional conventional and radial ply tires.
2. Directional conventional and radial ply tires.

TEST RESULTS

Table I summarizes the results of the Tire Durability Test in terms of test miles to removal and tread wear rate.

TABLE I

	Tire Groups				
	A	B	C	D	E
Average Test Miles Per Tire Sample ⁽¹⁾	10,022	8,604	15,040	7,509	2,541
Reason for Removal	Worn Smooth	Radial Cracks	Worn Smooth	Test Terminated	Test Terminated
Durability Rating, %	100	86	150	--	--
Tread Wear, Average Miles/Mil ⁽²⁾	6.1	29.9	12.2	16.3	20.3
Tread Wear Rating, %	100	490	200	267	333

(1) The sum of the failed tire mileages divided by the number of failed tires equals average test miles per tire sample.

(2) These averages are based on two measurement locations (shoulder) and do not include crown wear. (See Summary of Tire Tread Wear; Final, By Period.)

TEST RESULTS (Contd.)

Table II summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values (See Appendix A, "Ride" Study). A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

TABLE II

Condition	Tire Groups							
	A		F		D		E	
Front Tire psig	40	50	40	50	40	50	40	50
Rear Tire psig	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>
<u>"Ride" Index</u>								
Pavement								
#1, Smooth	0.35	0.68	0.51	0.50	0.60	0.30	0.50	0.31
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	<u>4.60*</u>	<u>2.00*</u>	<u>2.15*</u>	0.72
Secondary								
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.44	<u>0.98</u>	0.22	0.54
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.24	<u>1.90</u>	0.28	<u>1.40</u>
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	<u>0.91</u>	<u>4.30*</u>	0.75	<u>2.00*</u>
Cross-Country								
Rough	<u>2.7*</u>	--	<u>6.2*</u>	--	<u>10.2*</u>	--	<u>5.4*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

Table III summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Coer" Tanker, in terms of vehicle "Ride" index value (see Appendix A, Ride Study). A "ride" index of 1.91 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.6 to 0.9 G). (see GRAPH LEGEND, Figures 1 and 2.)

TABLE III

Vehicle Tire Group Condition	Vehicle "Ride" Indices							
	Model "C" Tournapull				"Coer" Tanker			
	A		F		A		F	
Inflation, Front, psig	40	50	40	50	40	50	40	50
Inflation, Rear, psig	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>
Pavement	<u>"Ride" Index</u>							
#1, Smooth	0.35	0.68	0.51	0.50	0.22	0.27	0.31	0.29
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	0.57	0.65	0.80	0.75
Secondary								
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.22	0.56	0.20	0.18
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.20	<u>1.40</u>	0.35	0.38
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	0.51	<u>0.90</u>	0.58	0.62
Cross-Country								
Rough	<u>2.70*</u>	--	<u>6.20*</u>	--	<u>5.70*</u>	--	<u>2.90*</u>	--

	Comparison of Mean Vehicle "Ride" Indices						
	Pavement		Secondary			Cross-Country	
	Smooth	Rough	Smooth	Smooth	Rough	Smooth	Rough
Coer @ 40-30 psig	0.27	0.63	0.21	0.28	0.53	<u>4.30*</u>	
"C" Pull @ 40-30 psig	0.43	<u>1.70</u>	0.52	0.45	0.89	<u>4.45*</u>	
Coer @ 50-40 psig	0.28	0.78	0.37	0.89	0.76	--	
"C" Pull @ 50-40 psig	0.59	<u>0.95</u>	<u>0.93</u>	<u>1.31</u>	<u>2.64*</u>	--	

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

Table IV summarizes the results of the Shallow Mud Traction Study (See Appendix 3, Mud Traction Study) of the directional tread conventional construction 29.5 - 25 tires and the non-directional tread radial ply 29.5 - 25 tires in terms of the influence of inflation pressure on tractive efficiency.

TABLE IV

<u>Inflation Pressure</u>	<u>Maximum Drawbar, Lbs.</u>		<u>% Travel Efficiency @ Maximum Drawbar</u>		<u>Static Ground-Lug Pressure PSI(2)</u>	
	<u>Group A</u>	<u>Group F</u>	<u>Group A</u>	<u>Group F</u>	<u>Group A</u>	<u>Group F</u>
55	9800	6100	17	26	228	113
45	8200	6800	30	31	146	85
35	7800	7150	30	27	109	62
25	7600	8750	40	32	87	56
15	(7550)(1)	9800	--	36	72	48

- (1) Extrapolated from inflation pressure-maximum drawbar curve of Groups A and F.
- (2) At 55 PSI the A Group penetrated to a depth of 2.25" in the crown area of the track and the F Group penetrated to a depth of 1.75" in the same area. At 25 PSI the A Group penetrated 0.25" evenly across track and the F Group penetrated to depth of 2.00" in the shoulder area of the track.

TEST RESULTS (Contd.)

Table V summarizes the calculated influence of the directional conventional tire (Group A) and the influence of the non-directional radial ply tire (Group F) on the shallow mud traction of the "Goer" Tanker.

TABLE V

Maximum Drawbar and Gradeability

Inflation Pressure	4 Wheels Driving				2 Wheels Driving			
	Group A		Group F		Group A		Group F	
	D.B.	Grade	D.B.	Grade	D.B.	Grade	D.B.	Grade
55	17950#	25%	11500#	16%	9600#	13%	6100#	8%
45	15100	21	12200	17	8100	11	6500	9
35	14350	20	13000	18	7700	11	6900	10
25	13650	19	15800	22	7300	10	8400	12
15	13650	19	17950	25	7250	10	9600	13

Maximum Drawbar and Gradeability at 75% Travel Efficiency

Inflation Pressure	4 Wheels Driving				2 Wheels Driving			
	Group A		Group F		Group A		Group F	
	D.B.	Grade	D.B.	Grade	D.B.	Grade	D.B.	Grade
55	8200#	12%	2800#	4%	4300#	6%	1500#	2%
45	8600	12	6500	9	4600	6	3450	5
35	9200	13	7900	11	5000	7	4200	6
25	10800	15	8600	12	5750	8	4600	6
15	--	--	11500	16	--	--	6100	8

D.B. = Drawbar

Grade = Gradeability

TEST RESULTS (Contd.)

Table VI summarizes the calculated performance of the "Goer" Tanker in terms of maximum traction (maximum performance) and at 75% travel efficiency.

TABLE VI

<u>Pressure</u>	<u>4 Wheel Drive Comparative Performance Ratings</u>			
	<u>Maximum Performance</u>		<u>@ 75% Travel Efficiency</u>	
	<u>Group A</u>	<u>Group F</u>	<u>Group A</u>	<u>Group F</u>
55	100%	64%	100%	33%
45	100	80	100	75
35	100	90	100	85
25	100	115	100	80
15	100	131	--	--

TEST RESULTS (Contd.)

Table VII summarizes the tire temperatures on pavement without regard for ambient or pavement temperatures as tire temperatures were recorded under equivalent conditions in each period.

TABLE VII

2,500 Mile Test Period	Tread Temperature of Test Tires on Pavement									
	Group A		Group B		Group C		Group D		Group E	
	Max. of	Avg. of	Max. of	Avg. of	Max. of	Avg. of	Max. of	Avg. of	Max. of	Avg. of
1st	Low temperatures recorded due to probe position.									
2nd, 3rd	230	199	275*	182	224	195	--	--	--	--
4th	220	198	245*	203	205	199	--	--	--	--
5th	265*	209	240*	209	234	213	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
Mean Temperature	202		198		202					
6th	--	--	--	--	200	189	216	203	256	232
7th	--	--	--	--	--	--	233	216	265	242
	--	--	--	--	--	--	--	--	--	--
Mean Temperature							210		237	

* Areas influenced by tread condition.

TEST RESULTS (Contd.)

Table VIII summarizes a comparison of vehicle fuel consumption as an index of tire rolling resistance.

TABLE VIII

	<u>Pavement</u>	<u>Average Miles per Gallon Secondary & Cross-Country</u>	<u>Over-All</u>
Group A	2.77	1.91	2.18
Group B	2.81	2.05	2.30
Group C	2.68	1.89	2.14

Over-All Rating % Based on Average Miles/Gallon

<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
100%	106%	98%

RECOMMENDATIONS

The scope of Project 20-1-110 has generated specific conclusions with respect to the tires and vehicles evaluated during this program. Deserving additional investigation to satisfy the specific questions arising from the results of this program are the following:

Tread Wear and Durability

The directional radial ply construction (Group E) and the non-directional conventional construction (Group D) tires should be subjected to additional durability test mileage before a valid performance comparison can be drawn for all tires considered in Project 20-1-110.

"Ride" Evaluation

The "Goer" Tanker vehicle exhibits a marked improvement in "Ride" over the commercial Model "C" Tournapull "test beds" on pavement and secondary roads, but not over cross-country trails with the inflation pressures recommended for the "Goer". As the "Goer" is equipped with a central self inflation system, all tires considered for "Goer" application should be judged in terms of cross-country "Goer" ride index vs inflation pressure curve in order to determine each tire group's tactical speed limit when negotiating cross-country.

"Goer" Mud Traction

In shallow mud the non-directional radial ply tires (Group F) were found to be as effective as the directional conventional construction (Group A) tires when the non-directional tires were inflated at 15 psig and the directional tires were inflated at 55 psig. The effect of this marked difference in inflation pressure and consequent reduction in ground contact pressure for the Group F tires should be measured in deep mud where underbody clearance not tire traction may be the factor limiting mobility. The directional radial tires (Group E) and the non-directional conventional construction tires should be evaluated in both shallow and deep mud to determine the separate effects of radial ply versus conventional construction and non-directional versus directional tread on mud traction. The influence of vehicle configuration should be assessed under these same conditions by measuring the percent effectiveness of the "Goer" rear wheel drive in mud.

DISPOSITION OF TIRES SUBJECTED TO TEST

Group A, Firestone Super Ground Grip Goer H.D. Directional (Control)

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
A-1	K 25300-14	10,022	Outside shoulder worn smooth.	None
A-2	K 25300-18	10,022	Both shoulders worn smooth.	None
A-3	K 25300-15	10,022	Inside shoulder worn smooth.	None
A-4	K 25300-16	10,022	Test terminated at this mileage.	None

Group B, U.S. Royal Tactical M.S. Radial Ply Construction Non-Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
B-1	EX 1808	7,231	Air loss above flipper.	B-6
B-2	XF 1867	10,876	Air loss at radial crack.	B-7
B-3	GR 1122	6,097	Tread separation inside shoulder.	B-5
B-4	GR 1351	13,306	Air loss at radial crack.	None
B-5	GR 1099	7,209	Test terminated.	None
B-6	GR 1177	5,512	Tread separation and air loss at radial crack.	Non-Test Spare
B-7	GR 1037	2,430	Test terminated	None

DISPOSITION OF TIRES SUBJECTED TO TEST (Contd.)

Group C, Firestone Super Ground Grip Goer Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
C-1	K 25500-5	15,040	Near worn smooth condition outside shoulder.	None
C-2	K 25500-4	15,040	Outside shoulder worn smooth.	None
C-3	K 25500-3	15,040	Test terminated.	None
C-4	K 25500-2	15,040	Test terminated.	None

Group D, Firestone NDMS

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
D-1	K 26400-5	7,509	Test terminated.	None
D-2	K 26400-4	7,509	Test terminated.	None
D-3	K 26400-1	7,509	Test terminated.	None
D-4	K 26400-3	7,509	Test terminated.	None

Group E, U.S. Royal Radial Ply Construction Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
E-1	CD 1732	2,541	Test terminated.	None
E-2	CD 1706	2,541	Test terminated.	None
E-3	CD 1714	2,541	Test terminated.	None
E-4	CD 1658	2,541	Test terminated.	None

SUMMARY OF TIRE TREAD WEAR

1. Final

Tire Group	Physical Dimensions				
	A	B	C	D	E
Total Miles	10,022	13,305(1)	15,040	7,509	2,541
Cross Section Growth, %	1.1	0.7(2)	1.6	1.7	0.0
Outside Diameter Growth, %	0.1	(3)	0.6	(3)	0.2
Final Shore "A" Hardness	57	57(2)	64	62	63

Tire Group	Tread Wear at Shoulders				
	A(4)	B(5)	C(6)	D	E
Mils Loss, Group	9912	3296	8181	3686	1001
Miles/Mil, Group	6.1	29.9	12.2	16.3	20.3
Rating, Group (Based on Miles/Mil)	100	490	200	267	333
Mils Loss, Front	4256	1414	3385	1724	491
Miles/Mil, Front	7.1	35.4	14.8	17.4	20.7
Rating, Front (Based on Miles/Mil)	100	499	208	245	292
Mils Loss, Rear	5656	1882	4796	1962	510
Miles/Mil, Rear	5.3	25.7	10.4	15.3	19.9
Rating, Rear (Based on Miles/Mil)	100	485	196	289	375
% Worn, Group	79.2	31.0	65.3	32.3	8.4
% Worn, Front	34.0	13.3	27.0	15.1	4.1
% Worn, Rear	45.2	17.7	38.3	17.1	4.3

- (1) Tire B-4 accumulated 13,306 test miles before failure. All other original test tires and one replacement tire failed prior to this mileage.
- (2) Based on the seven samples tested.
- (3) Due to tire design no crown measurements could be taken to correct Outside Diameter on these groups.
- (4) One or both of the shoulder measurement areas had worn away on three of the four test tires at 10,022 test miles. Figures shown represent wear rates through 7,522 test miles (last measurement period before worn smooth condition).
- (5) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.
- (6) Figures based on 12,525 mile measurement period due to one tire worn smooth at 15,040 mile measurement period.

SUMMARY OF TIRE TREAD WEAR (Contd.)

1. Final (Contd.)

As the only measurement positions common to all tire groups tested were the shoulders it was felt that a basis of comparison should be drawn from these data; however, even this must be weighed by the fact that there is a wide variation in mileage between the individual groups tested and the ratings even though based on miles per mil are on a total mileage; therefore, the figures do not reflect a true figure as it would if all tires had run equal miles.

A further comparison can be made on the three groups of tires whose design permitted a crown measurement. The following data indicates the tread wear across the tread face rather than in the fastest wearing area.

Tire Group	Tread Wear at Shoulders and Crown		
	A	C	E
Total Miles	7,522	12,525	2,541
Mils Loss, Group	11351	9861	1594
Miles/Mil, Group	8.0	15.2	19.1
Rating, Group (Based on Miles/Mil)	100	190	239
Mils Loss, Front	5179	4347	787
Miles/Mil, Front	8.7	17.3	19.4
Rating, Front (Based on Miles/Mil)	100	199	223
Mils Loss, Rear	6172	5514	807
Miles/Mil, Rear	7.3	13.4	18.9
Rating, Rear (Based on Miles/Mil)	100	184	259
% Worn, Group	61.3	53.2	8.9
% Worn, Front	28.0	23.5	4.4
% Worn, Rear	33.3	29.7	4.5

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period

Tread wear measurements are based on two shoulder measurement locations on the B Group (U.S.) tires and on two and three locations, two shoulder and one crown, on the A and C Groups (Firestone). The shoulder measurements are located 9 inches each side of crown, and are taken in a position around the circumference of the tire. The A, B and C Groups are compared on the basis of two measurement locations and the A and C Groups are additionally compared on the basis of three measurement locations.

Tire Group	Firestone				U.S.
	A		C		B
Miles @ Meas.	2,520		2,520		2,520
No. of Meas. Locations	2	3	2	3	2
Mils Loss (Group)	2239	2862	848	1465	584
Miles/Mil (Group)	9.0	10.6	23.8	20.6	34.5
% Worn (Group)	17.9	15.5	6.8	7.9	5.5
Mils Loss (Front)	1039	1416	356	719	331
Miles/Mil (Front)	9.7	10.7	28.3	21.0	30.5
% Worn (Front)	16.5	15.2	5.7	7.8	6.3
Mils Loss (Rear)	1200	1446	492	746	253
Miles/Mil (Rear)	8.4	10.5	20.5	20.3	39.8
% Worn (Rear)	19.1	15.7	7.9	8.1	4.7
Miles @ Meas.	5,022		5,122		5,022
Mils Loss (Group)	6043	6177	2643	3508	1243
Miles/Mil (Group)	6.7	8.0	15.2	17.2	32.3
% Worn (Group)	48.2	37.7	21.1	18.9	11.7
Mils Loss (Front)	2657	3180	1215	1611	539
Miles/Mil (Front)	7.6	9.5	10.5	17.8	33.5
% Worn (Front)	42.2	34.2	19.4	18.2	11.3
Mils Loss (Rear)	3386	3797	1428	1897	644
Miles/Mil (Rear)	6.0	7.9	14.0	16.6	31.2
% Worn (Rear)	54.1	41.1	22.9	19.6	12.0
Miles @ Meas.	7,522		7,522		7,498(1)
Mils Loss (Group)	9912	11351	4318	5404	1808
Miles/Mil (Group)	6.1	8.0	13.6	16.8	32.9
% Worn (Group)(2)	79.2	61.3	34.6	29.9	13.6
Mils Loss (Front)	4256	5179	1879	2499	944
Miles/Mil (Front)	7.1	8.7	16.0	18.1	31.7
% Worn in Front(2)	34.0	28.0	15.0	13.5	7.1
Mils Loss (Rear)	5656	6172	2439	2905	864
Miles/Mil (Rear)	5.3	7.3	12.2	15.5	34.1
% Worn in Rear(2)	45.2	33.3	19.6	15.7	6.5

(1) Due to tire failures in this group 24 miles of cross-country operation was lost during tire replacement; therefore, these figures are based on 5 tires.

(2) % Worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period (Contd.)

Tire Group	Firestone			U.S.
	A	C		B
Miles @ Meas.	10,022	10,022		10,024(1)
No. of Meas. Locations	1*	2	3	2
Mils Loss (Group)	2429	6210	7551	2549
Miles/Mil (Group)	16.5	12.9	15.9	31.5
% Worn (Group)(2)	40.5	49.5	40.8	16.0
Mils Loss (Front)	1578	2589	3394	1140
Miles/Mil (Front)	12.7	15.5	17.7	35.2
% Worn in Front(2)	26.3	20.7	18.3	7.1
Mils Loss (Rear)	851	3621	4157	1409
Miles/Mil (Rear)	23.6	11.1	14.5	28.5
% Worn in Rear(2)	14.3	28.9	22.4	8.8

Tire Group	Firestone		U.S.	Firestone
	C		B(3)	D
Miles @ Meas.	12,525		12,527	2,503
No. of Meas. Locations	2	3	2	2
Mils Loss (Group)	8181	9861	3296	1357
Miles/Mil (Group)	12.2	15.2	29.9	14.8
% Worn (Group)(2)	65.3	53.2	31.0	11.9
Mils Loss (Front)	3385	4347	1414	791
Miles/Mil (Front)	14.8	17.3	35.4	12.7
% Worn in Front(2)	27.0	23.5	13.3	6.9
Mils Loss (Rear)	4796	5514	1882	566
Miles/Mil (Rear)	10.5	13.6	25.7	17.7
% Worn in Rear(2)	38.3	29.7	17.7	5.0

* Some shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures for B Group based on 6 tires.

(2) % Worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

(3) Figures for B Group based on 7 tires.

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period (Contd.)

Tire Group	Firestone C	U. S. B(1)	Firestone D
Miles @ Meas.	15,040	13,306	5,003
No. of Meas. Locations	1*	2	2
Mils Loss (Group)	2161	3296	2286
Miles/Mil (Group)	27.8	29.9	17.5
% Worn (Group)(2)	36.0	31.0	20.0
Mils Loss (Front)	1146	1414	1185
Miles/Mil (Front)	26.2	35.4	16.9
% Worn in Front(2)	19.1	13.3	10.4
Mils Loss (Rear)	1015	1882	1101
Miles/Mil (Rear)	29.6	25.7	18.2
% Worn in Rear(2)	16.9	17.7	9.6

Tire Group	Firestone D	U.S. E	
Miles @ Meas.	7,509	2,541	
No. of Meas. Locations	2	2	3
Mils Loss (Group)	3686	1001	1594
Miles/Mil (Group)	16.3	20.3	19.1
% Worn (Group)(2)	32.3	8.4	8.9
Mils Loss (Front)	1724	491	787
Miles/Mil (Front)	17.4	20.7	19.4
% Worn in Front(2)	15.1	4.1	4.4
Mils Loss (Rear)	1962	510	807
Miles/Mil (Rear)	15.3	19.9	18.9
% Worn in Rear (2)	17.1	4.3	4.5

* One tire in group had shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.

(2) % Worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

SUMMARY OF TIRE TEMPERATURES

Heat Build-up 1st Period: After tire inflation pressures had been determined tire tread temperatures were taken for six consecutive operating days immediately after the vehicles had completed the pavement portion of the day shift operation. Pavement tire temperatures and pressures for the 2,520 miles covered by 1st period of operation are as follows:

Averages of Tread Temperatures (°F) and Tire Pressures (psig)

Tire Group			A-Firestone Control					B-U.S. Rubber Exp.				C-Firestone Exp.								
Vehicle			C-1					C-2				C-3								
psig Cold Start			F	35	R			25	F	40	R			25	F	35	R			25
Pave	Amb	°F	psig					°F	psig				°F	psig				°F		
°F	(1)	(2)	Cold	End	Inc	Temp		Cold	End	Inc	Temp		Cold	End	Inc	Temp				
71	55	37	F	36.1	48.6	12.5	164.2		41.0	50.2	9.2	148.0		36.0	47.8	11.8	161.			
			R	26.0	36.3	10.3	177.7		26.1	34.1	8.0	155.9		25.9	34.8	8.9	182.			

(1) At time of temperature measurement.

(2) At cold starting time.

Heat Build-up 2nd and 3rd Periods: Pavement tire temperatures and pressures for the 5,002 miles covered by these periods of operation.

Tire Group	Group A	Group B*	Group C
Maximum Tire Temperature	230°F	211°F	224°F
Average Tire Temperature	199°F	182°F	195°F
Maximum Tire Pressure	51 psig (35 cold)	53.5 psig (40 cold)	58 psig (40 cold)
Average Tire Pressure Build-up (All Tires)	13 psig	11 psig	13 psig
Maximum Ambient	67°F	67°F	67°F
Average Ambient	60°F	60°F	60°F

* 275°F maximum at separated area.

Note: Average tread temperatures for secondary road operation are Group A, 199°F; Group B, 186°F; Group C, 189°F.

SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 4th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

<u>Tire Group</u>	<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
Maximum Tire Temperature °F	220	245	205
Average Tire Temperature °F	198	203	199
Maximum Tire Pressure, psig	51.5 (35 cold)	56.0 (40 cold)	58.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	13	12	14
Maximum Ambient Temperature °F	70	70	70
Average Ambient Temperature °F	62	62	62

Heat Build-up 5th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

<u>Tire Group</u>	<u>Group B</u>	<u>Group C</u>	<u>Group D</u>
Maximum Tire Temperature °F	265(1)	240	234
Average Tire Temperature °F	209	209	213
Maximum Tire Pressure, psig	52.0 (40 cold)	55.0 (40 cold)	52.0 (40 cold)(2)
Average Tire Pressure Build-up (All Tires) psig	11	14	12
Maximum Ambient Temperature °F	83	84	83
Average Ambient Temperature °F	82	83	74

(1) See TEST DATA, 3. Tread Temperatures & Tire Pressures.

(2) Tire pressures were originally set at 35 psig front and 25 psig rear (cold starting). On 5/18/63 at 716 total test miles tire inflation (cold starting) was increased to 40.0 psig front and 30.0 psig rear.

SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 6th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group C(1)</u>	<u>Group D</u>	<u>Group E</u>
Maximum Tire Temperature °F	200	216	256
Average Tire Temperature °F	189	203	232
Maximum Tire Pressure, psig	52.5 (40 cold)	56.0 (40 cold)	54.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	11	12	11
Maximum Ambient Temperature °F	55	84	84
Average Ambient Temperature °F	55	69	69

Heat Build-up 7th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group D(1)</u>	<u>Group E(1)</u>
Maximum Tire Temperature °F	233	265
Average Tire Temperature °F	216	242
Maximum Tire Pressure, psig	55.0 (40 cold)	55.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	13	12
Maximum Ambient Temperature °F	76	76
Average Ambient Temperature °F	76	76

(1) Tire temperatures were only taken once during this period.

TIRE ROLLING RESISTANCE EXPRESSED IN MILES PER GALLON

At the completion of three measurement and rotation periods wherein each tire group operated one period on each vehicle the following fuel consumption data was compiled.

	<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
Miles per Gallon, Pavement	2.77	2.81	2.68
Rating	100	101	97
Miles per Gallon, Secondary and Cross-Country	1.91	2.05	1.89
Rating	100	107	99
Miles per Gallon, Total	2.18	2.30	2.14
Rating	100	106	98

DRIVER EVALUATION OF "RIDE" BY TIRE GROUPS

The first driver reaction to ride by groups was taken at the end of the 7,500 mile period; wherein each driver polled had driven each tire group on each test vehicle thereby eliminating the possibility of one vehicle influencing tire ride.

The following table indicates drivers observed ride:

Group C - Best on pavement and secondary.

Group B - Poorest on pavement and secondary.

Group A, B, C - Equal on Cross-country.

The next poll taken was at the 10,000 mile point and was a rating by the drivers of the three tire groups on the courses on which they had the most driving time. Those who placed the B Group in first place on pavement and secondary qualified the rating to the speed ranges above or below that in which lope was developed.

Preference Driver #	Pavement							Secondary							Cross-Country						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1st	B	C	-	C	C	-	-	C	C	A	B	B	C	A	C	-	C	B	-	C	C
2nd	C	A	-	B	A	-	-	A	A	C	C	A	A	C	A	-	A	C	-	A	A
3rd	A	B	-	A	B	-	-	B	B	B	A	C	B	B	B	-	B	A	-	B	B

As tire groups were removed from test and substitute groups inserted a final observed rating was necessary covering the new groups.

The following table shows a tire Group F which was of similar construction and design as the Group B tires which were removed from test prematurely due to failures:

Preference Driver #	Pavement							Secondary							Cross-Country						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1st	DE	DE	-	DE	DE	-	-	E	E	DE	E	DE	E	-	FE	-	FE	FE	-	FE	FE
2nd	F	F	-	F	F	-	-	DF	DF	F	DF	F	DF	-	D	-	-	D	D	D	D

TEST PROGRAM

Test Courses

Pavement Operation - The first week of test operation on pavement was conducted on Highway 95A from Silver Springs to the Fort Churchill turnaround. This provided 7.1 miles of pavement operation per turnaround; however, due to high lope exciters which prevented operation of over 1800 RPM, 5th gear at the Fort Churchill end of course it was deemed necessary to eliminate the last 3.1 miles of the original course, and a new turnaround was established at the Weeks road (secondary test course) junction.

After 6540 total miles of pavement operation and 908 laps the paved course #1 from Silver Springs to Weeks turnaround on Highway 95A deteriorated to the point that a course change was required.

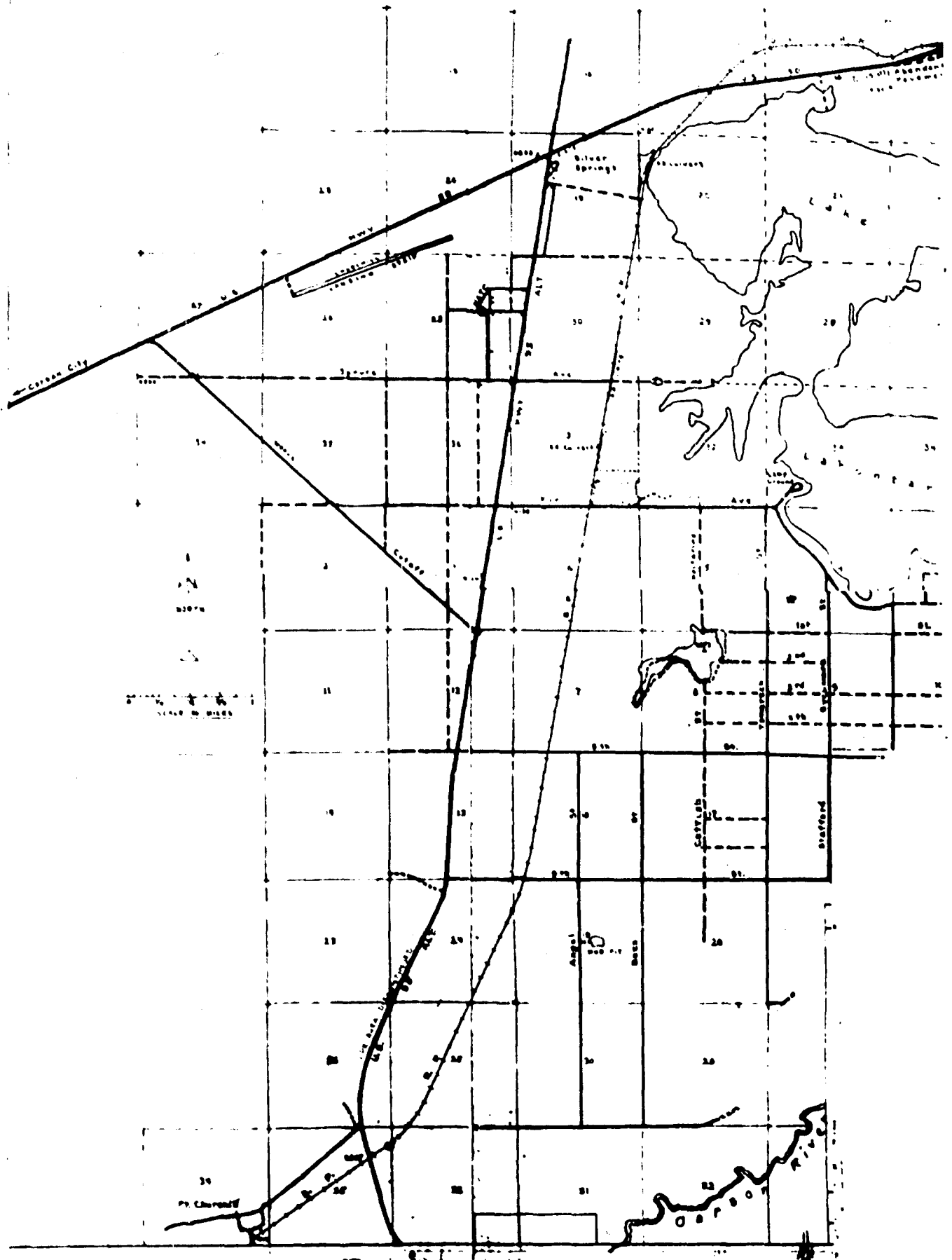
The new route (#2) on abandoned paved highway from Silver Springs to junction of Highways 50 and 95 permitted 194 miles of pavement operation per shift instead of the 104 miles per shift on test course #1, which was limited by Highway Department permit. The length of test course #2 permits an average vehicle speed of 25.8 MPH as opposed to 24.5 MPH on test course #1.

Secondary Operation - A variety of courses was used throughout the test due to the destructive forces applied by the vehicles and aggressive tire designs. As one area became a lope generator wherein maximum speed could not be sustained without undue forces on vehicle and driver, an identical test area was used to permit the destroyed course to be maintained. A noticeable improvement in course condition developed in the third 2500 mile period. The courses appeared to be "packing" a more stable surface and the cause is attributed to the considerable reduction in the aggressive lug penetration of the A and C tire groups due to wear. This same condition was also apparent on the cross-country course.

Cross-Country Operation - The same course was maintained throughout the test with the exception of the alkali flats at the north end of course which became impassable during rain storms.

The following map indicates test courses used during test with the exception of pavement course #2.

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Project 20-1-110

Upper Photograph

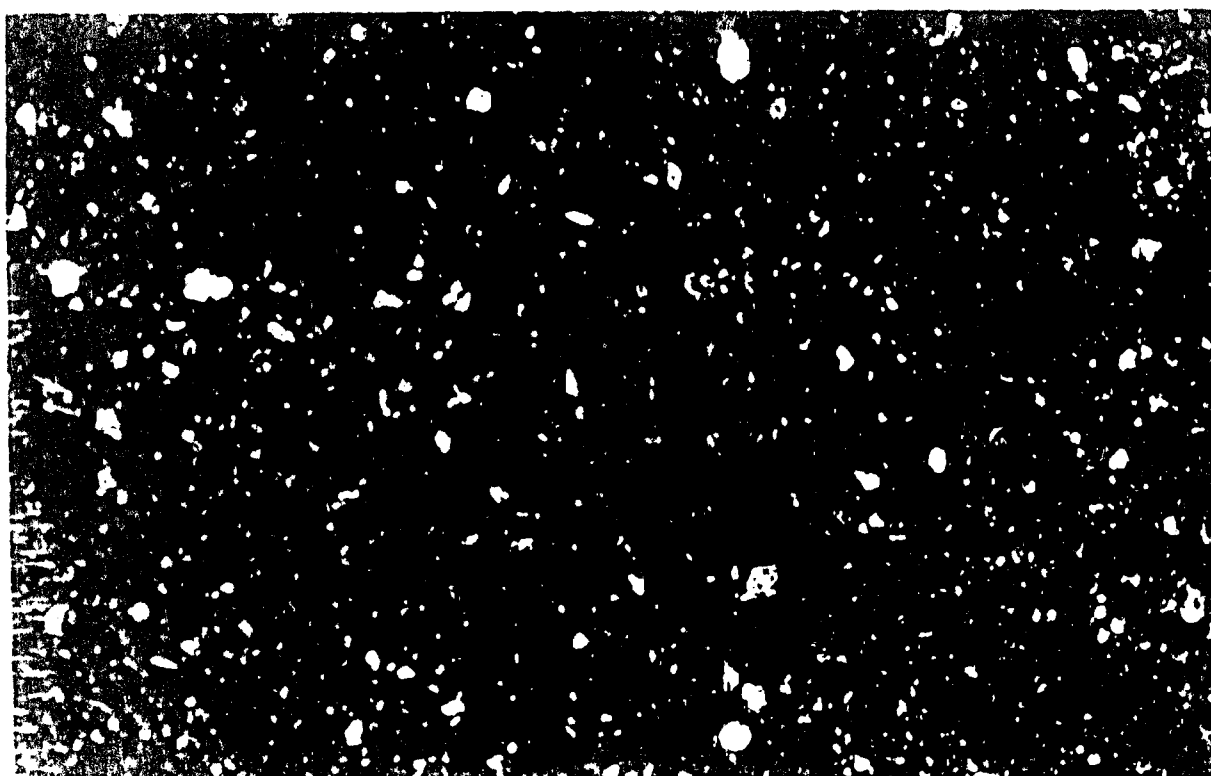
Pavement Deterioration of Course #2
Produced by the Random Cyclic Excitations of Test Vehicles

Lower Photograph

Texture of Pavement Surface Course #2

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FINAL REPORT

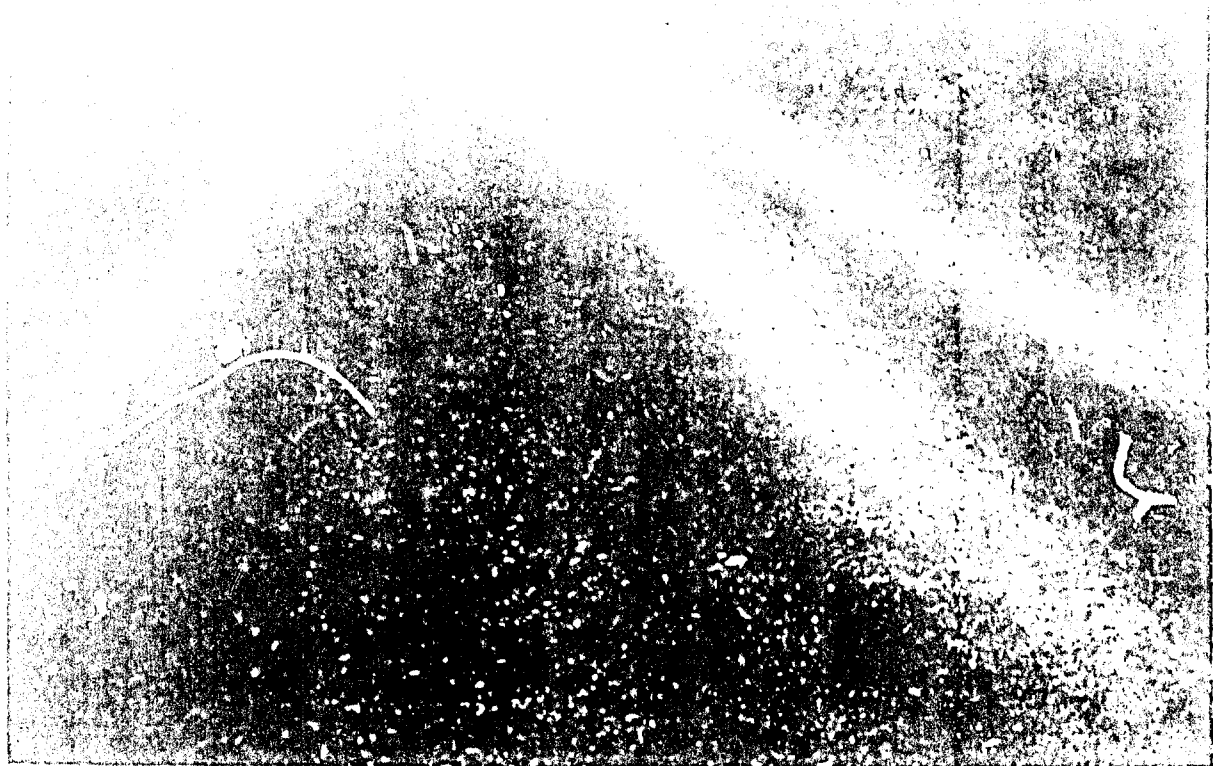
Project 20-1-110

Upper Photograph

Secondary Gravel Test Course (Weeks Road)

Lower Photograph

Cross-Country Test Course Hill Section



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TEST PROGRAM (Contd.)

Test Speeds

Cross-Country - Maximum allowed by test course and vehicle conditions.

Gravel-Secondary - Maximum allowed by test course and vehicle conditions.

Highway - Maximum allowed by test course and vehicle conditions.

Tire Break-in. Vehicle operating speeds were reduced to one-half of required test speeds for first 16 hours of operation.

Tire Inflation Pressures

At start of test, tire pressures were established for all three groups at 35 psig, front axle and 30 psig, rear axle. It was found that on pavement and secondary road operation the degree of lops or bounce of the vehicles was so extreme that continued operation was not safe for personnel nor could the equipment withstand continued impact of the G forces involved. Tire pressures were varied in 5 psig increments, front and rear, at cold start as tabulated below, until a combination was established for each tire group that would permit safe convoy operation of the three vehicles at acceptable speeds for each type of terrain.

Tire Group	Miles at psig Settings								
	A			B			C		
	Miles	F	R	Miles	F	R	Miles	F	R
	446	35	30	359	35	30	446	35	20
	2074	35	25		30	30	2074	35	25
					35	25			
				476	35	35			
					35	45			
					40	45			
					50	45			
					40	20			
				1685	40	25			

On 4 March 1963 at 3267 test miles at the beginning of 1st shift, tire inflation of the C Group tires was raised, at the manufacturer's request, by 5 psig (40 front, 30 rear) to alleviate fast shoulder wear.

When Groups D and E entered the test program the tire inflation pressures were established at 40 psig front and 30 psig rear for purposes of tread wear evaluation.

TEST PROGRAM (Contd.)

Test Vehicles

Three (3) commercial vehicles were loaded to simulate a "Goer" Tanker GVW of 70-72000 lbs. Axle load distribution was approximately 54% front and 46% rear. Test bed vehicles had equivalent torque and braking characteristics. With the exception of failed parts replacement the vehicles were maintained throughout test by the Nevada Automotive Test Center using those methods approved by the vehicle manufacturer.

Vehicle Weights

Vehicle	<u>C-1</u>	<u>C-2</u>	<u>C-3</u>	<u>"Goer"(1)</u>
Front Axle, Lbs.	38,800	39,000	38,400	38,370
Rear Axle, Lbs.	<u>32,000</u>	<u>31,900</u>	<u>31,000</u>	<u>33,450</u>
Gross Vehicle Weight	70,000	70,900	69,400	71,820
Left Rear, Lbs.	16,000	16,000	15,000	--
Right Rear, Lbs.	<u>16,250</u>	<u>16,200</u>	<u>15,600</u>	--
	32,250	32,200	30,600	

(1) Goer vehicle was used in engineering studies and not on tire durability tests.

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TEST PROGRAM (Contd.)

Test Mileage

Under the original test directive each group of tires was to be run 20,000 miles divided as follows:

- 20% - Cross-Country
- 40% - Secondary Gravel
- 40% - Highway

The following table indicates the miles accumulated and average miles per hour in each period throughout test.

Period	Groups Run	Highway Pavement		Secondary Gravel		Cross Country		Total	
		Miles	Avg. MPH	Miles	Avg. MPH	Miles	Avg. MPH	Miles	Avg. MPH
1st	A, B & C	1,000	21.9	1,000	19.1	520	9.2	2,520	16.3
2nd	A, B & C	1,000	24.4	1,002	20.7	500	8.9	2,502	17.4
3rd	A, B & C	1,000	22.7*	1,000	19.9*	500(1)	9.6	2,500	17.1
4th	A, B & C	1,000	25.7	1,000(2)	21.7	500(2)	9.8	2,500	18.3
5th	B, C & D(3)	1,003	23.5**	1,000	23.1	500	9.2	2,503	17.6
6th	B(4), C(5) D & E(6)	1,000	25.7	1,000	21.7	500	9.9	2,500	18.5
7th	D & E	1,006	26.1	1,000	23.4	500	9.7	2,506	18.8

- (1) B group tires accomplished 476 miles of cross-country due to tire failures.
- (2) B group tires accomplished 524 miles of cross-country and 1,002 miles of secondary.
- (3) D group replaced A group at start of this period due to worn smooth condition of A group.
- (4) B group terminated during this period—replaced with E group. B group accomplished 358 miles pavement, 260 miles secondary and 161 miles of cross-country for a total of 779 miles.
- (5) C group due to ride and lone study accomplished 1,015 miles pavement, 1,000 miles secondary and 500 miles cross-country for a total of 2,515 miles this period.
- (6) E group, which replaced B group, started test in the middle of 6th period and finished in the middle of 7th period. This group accomplished 1,013 miles pavement, 1,026 miles secondary and 502 miles cross-country for a total of 2,541 miles.
- * Average speed reduced; 1/2 speed, 21 hours break-in of replacement B group.
- ** Average speed reduced; 1/2 speed, 16 hours break-in of new D group tires.

TEST PROGRAM (Contd.)Test Mileage (Contd.)

The following table indicates the test miles accumulated by each tire under each of the three conditions.

<u>Tire Code</u>	<u>Highway Pave Miles</u>	<u>% of Total Miles</u>	<u>Secondary Gravel Miles</u>	<u>% of Total Miles</u>	<u>Cross-Country Miles</u>	<u>% of Total Miles</u>	<u>Total Miles</u>
A-1	4,000	40	4,002	40	2,020	20	10,022
A-2	4,000	40	4,002	40	2,020	20	10,022
A-3	4,000	40	4,002	40	2,020	20	10,022
A-4	4,000	40	4,002	40	2,020	20	10,022
B-1	3,000	41	2,784	39	1,447	20	7,231
B-2	4,406	40	4,342	40	2,128	20	10,876
B-3	2,374	39	2,539	42	1,184	19	6,097
B-4	5,361	40	5,264	40	2,681	20	13,306
B-5	2,987	41	2,725	38	1,497	21	7,209
B-6	2,141	39	2,220	40	1,151	21	5,512
B-7	955	39	922	38	553	23	2,430
C-1	6,018	40	6,002	40	3,020	20	15,040
C-2	6,018	40	6,002	40	3,020	20	15,040
C-3	6,018	40	6,002	40	3,020	20	15,040
C-4	6,018	40	6,002	40	3,020	20	15,040
D-1	3,009	40	3,000	40	1,500	20	7,509
D-2	3,009	40	3,000	40	1,500	20	7,509
D-3	3,009	40	3,000	40	1,500	20	7,509
D-4	3,009	40	3,000	40	1,500	20	7,509
E-1	1,013	40	1,026	40	502	20	2,541
E-2	1,013	40	1,026	40	502	20	2,541
E-3	1,013	40	1,026	40	502	20	2,541
E-4	1,013	40	1,026	40	502	20	2,541

TEST PROGRAM (Contd.)

Tire Contact Areas

Contact prints were made at start of test of the right front tire of each test group at 30 psig. Additional contact prints were taken on the Group A and B tires at 15, 20 and 40 psig inflation. The gross and net contact areas for each tire and the ratio of net to gross is tabulated below.

Vehicle Number Tire Code	15			20			30			40		
	C-1	C-2		C-1	C-2		C-1	C-2	C-3	C-1	C-2	C-3
	A-2	B-2		A-2	B-2		A-2	B-2	C-2	A-2	B-2	C-2
Gross Area, in ²	756.3	726.2		633.7	604.4		495.7	484.3	495.7	419.6		435.0
Net Area, in ²	269.2	404.8		253.4	377.9		192.3	284.4	192.3	156.9		255.5
Ratio, Gross to Net	2.81	1.79		2.50	1.60		2.58	1.68	2.58	2.67		1.70
Net % of Gross	35.5	55.7		40.0	62.5		38.8	59.4	38.8	37.4		58.7
101/Gross Area*	25.7	26.9		30.6	32.3		39.1	40.3	38.7	46.2		44.8
101/Net Area*	72.1	48.2		76.6	51.6		100.9	68.6	99.8	123.6		76.3

* Based on R.F. weight, lbs. A= 19,400 B= 19,500 C= 19,200

Group A: Firestone Super Ground Grip Goer H.D., Control

Group B: U.S. Royal Tactical M.S.

Group C: Firestone Super Ground Grip Goer Directional

LOG CONTACT PRESSURE

29.5 25 COED TIDES

PROJECT 20-1-110

20

30

40

50

60

70

INFLATION, PSIG

GROUP A

DIRECTIONAL CONVENTIONAL

GROUP B

NON-DIRECTIONAL RADIAL

100

200

300

400

CONTACT AREA NET INCH²

11-1-83

11-1-83

11-1-83

TEST PROGRAM (Contd.)

Test Tire Measurements

The following measurements were taken and recorded prior to start and at every 2300-2500 miles of tire travel:

Outside Diameter

Shore Hardness - 3 places

Tread Depth - 6 places inside and outside

Tread Cutting (number and total length) minimum 2" length, 1/4" side-wall and to fabric in tread

Cross Section - 3 places

Contact Print - 30 psip on right front tire each group at start of test

Tire Rotation

<u>At End of Test Period</u>	<u>Tire Miles Accumulated</u>	<u>Rotation Schedule</u>	<u>Tire Groups Affected</u>
#1	2,520	Vehicle to vehicle-fixed wheel position.	A, B, C
#2	2,502	Diagonally front-to-rear-vehicle to vehicle.	A, B, C
#3	2,500	Vehicle to vehicle-fixed wheel position.	A, B, C
#4	2,500	Vehicle to vehicle-fixed wheel position.	B, C, D
#5	2,503	Vehicle to vehicle-fixed wheel position.	B, C, D
#6	2,500	Vehicle to vehicle-fixed wheel position.	D, E
#7	2,506		Test Terminated

Additional Tests

Due to test termination prior to the 20,000 mile limit it was considered advisable to investigate two phenomena which occurred during the test. A noticeable difference in the "ride" characteristics between tire groups was found and an observed deficiency of the non-directional radial construction tires in shallow mud. These conditions were further investigated by means of instrumentation and are covered in Appendix A "Ride Study" and Appendix B "Shallow Mud Traction".

SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS

Group A Tires

	Gallons		Total Fuel
	Pavement Fuel	Off-Road Fuel	
1st Period, 0-2520 Miles, Vehicle C-1	361.2	782.3	1143.5
2nd Period, 2520-5022 Miles, Vehicle C-3	370.2	788.1	1158.3
3rd Period, 5022-7522 Miles, Vehicle C-2	352.0	791.6	1143.6
4th Period, 7522-10022 Miles, Vehicle C-1	360.0	723.9	1083.9
Total	1443.4	3085.9	4529.3
Miles per Gallon	2.77	1.95	2.21
Rating	100	100	100

Group B Tires

1st Period, 0-2520 Miles, Vehicle C-2	371.8	728.9	1100.7
2nd Period, 2520-5022 Miles, Vehicle C-1	362.4	745.2	1107.6
3rd Period, 5022-7498 Miles, Vehicle C-3	332.2	707.3	1039.5
4th Period, 7498-10024 Miles, Vehicle C-2	329.2	726.3	1055.5
5th Period, 10024-12527 Miles, Vehicle C-1	336.0	655.1	991.1
6th Period, 12527-13306 Miles, Vehicle C-3	120.7	216.0	336.7
Total	1852.3	3778.8	5631.1
Miles per Gallon	2.89	2.10	2.36
Rating(1)	104	108	107

Group C Tires

1st Period, 0-2520 Miles, Vehicle C-3	377.9	787.8	1165.7
2nd Period, 2520-5022 Miles Vehicle C-2	390.9	813.9	1204.8
3rd Period, 5022-7522 Miles, Vehicle C-1	349.8	789.7	1139.5
4th Period, 7522-10022 Miles, Vehicle C-3	344.8	773.0	1117.8
5th Period, 10022-12525 Miles, Vehicle C-2	356.6	686.4	1043.0
6th Period, 12525-15040 Miles, Vehicle C-1	355.4	730.4	1085.8
Total	2175.4	4581.2	6756.6
Miles per Gallon	2.77	1.97	2.23
Rating(1)	100	101	101

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.

SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS (Contd.)

Group D Tires

	Gallons		
	<u>Pavement Fuel</u>	<u>Off-Road Fuel</u>	<u>Total Fuel</u>
5th Period, 0-2503 Miles, Vehicle C-3	352.0	682.9	1034.9
6th Period, 2503-5003 Miles, Vehicle C-2	318.2	701.1	1019.3
7th Period, 5003-7509 Miles, Vehicle C-1	334.7	703.6	1038.3
Total	1004.9	2087.6	3092.5
Miles Per Gallon	2.99	2.16	2.43
Rating(1)	108	111	110

Group E Tires

6th-7th Period, 0-2541 Miles, Vehicle C-3	333.5	739.9	1073.4
Total	333.5	739.9	1073.4
Miles per Gallon	3.04	2.07	2.37
Rating(1)	110	106	107

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.

VEHICLE DURABILITY

The three Model "C" Tournapulls used in this Tire Durability Test to simulate the Army Goer Vehicle experienced a minimal parts mortality record. Other than normal vehicle service and preventive maintenance the following table indicates all failures experienced during test.

<u>Veh. #</u>	<u>Date</u>	<u>Mileage @ Failure</u>	<u>Description of Failure</u>	<u>Cause of Failure</u>	<u>Disposition</u>
C-1	3/11/63	4,799	Cable, Apron, broken.	Believed that apron limit switch was misaligned.	Replaced cable and aligned limit switch.
C-1	4/5/63	8,431	Cab Bolt, right front missing.	Unknown.	Replaced.
C-1	5/17/63	10,725	DC charging rate low.	DC Rectifiers.	Replaced.
C-1	5/27/63	12,292	DC charging rate low.	Flux bridge not property adjusted.	Installed shims in flux bridge.
C-1	6/12/63	18,309	DC charging rate low.	Deficient coil in transformer.	Replaced trans- former.
C-2	4/5/63	8,431	Hose, Air Tank Outlet, leaking.	Ruptured.	Replaced.
C-2	6/4/63	16,341	Can Arm Ball Cap, right, 2 cap screws broken.	Unknown.	Replaced.
C-2	6/4/63	16,341	Wheel Studs, left missing (Wheel came off bending brake drum).	Wheel Studs not properly tightened.	Replaced brake drum, tapped wheel stud holes and replaced wheel stud
C-2	6/8/63	17,609	Points, Steering Relay, left, burn- ed and not making contact.	High resistance.	Replaced left steer- ing points. Note: Points had been dressed several times prior to replacement.
C-3	3/30/63	7,522	Cable, Can Hoist, flattened and frayed.	Rubbing against can sheave side plate due to being laced incorrectly.	Replaced cable and laced correctly.
C-3	4/2/63	7,777	Hose, Rear Brake, main line broken at brass fitting.	Unknown.	Replaced.

VEHICLE DURABILITY (Contd.)

<u>Veh. #</u>	<u>Date</u>	<u>Mileage @ Failure</u>	<u>Description of Failure</u>	<u>Cause of Failure</u>	<u>Disposition</u>
C-3	4/5/63	8,517	Pin & Bearing, Apron Sheave, damaged.	Believed that apron cable forced through sheave while looped.	Replaced pin and bearing. Welded torn section of sheave side cover.
C-3	6/8/63	17,600	Points, Steering Relay, left burned and not making contact..	High resistance.	Replaced left steer- ing points. Note: Points had been dressed several times prior to replacement.

TEST DATA

1. TIME MEASUREMENT SUMMARY

Best Available Copy

TIRE MEASUREMENT SUMMARY

HOGGES TRANSPORTATION INC.

128MS

Project 20-1-110 Tire Group A-1 Hfg. Descr. Firestone Super Ground Grip Gper H.D. Cont
 Date Feb. 1963 Tire Size 29.5-25 P.K. 16 Ribs Lugs Type paig Rotation Voids 143

Pos.	Meas.	Miles	Lb/Gal	Loss	Inc	Inc	Sec	Profile	Cur.	Orig.	Tread	Depth	& Tread	Loss	Miles	Miles/Hil	Worn	Est
LF	Orig.	0			73.76	30.52			57	1.575	1.500	1.575						
C-1	2520	2520			74.22	30.84			57	1.463	1.338	1.264						
					0.6	1.0				0.112	0.162	0.311						
LF	2502	5022			74.32	30.96			58	1.382	1.264	0.815						
C-3					0.8	1.4				0.181	0.074	0.449						
PR	2500	1522			74.06	30.07			57	0.437	1.244	0.446						
C-2					0.4	1.1				0.846	0.020	0.355						
RR	2500	10022			73.98	30.80			57	WA	1.160	0.102						
C-1					0.3	0.2					0.084	0.358						
TEST																		
TERMINATED		10022																

✓ Tread Loss of Crown Measurement Only % tread on outside shoulder worn away

Miles & Loss	Miles/Mil	Worr.
Per. Cum.	Per. Cum.	Per Cum Co.
4650		
8065		
85	12.9	126 -
3761		
704	10.7	15.1 27.7
2141		
1720	6.1	263 54.0
✓ 340	✓ 29.5	✓ 22.7

⑦

HODGES TRANSPORTATION INC.

Form 128MS

Project 20-1-110 Tire Group A-2

Mfg. Descr.

Firestone Super Ground Grip Goer H.D.D.

1963 Tire Size 29.5-29

91.

Luas Type

paid

Rotation

Veh.-Veh. ea. 2500

TABLE 1

[illegible]

Voids 1,2,3

Station	Loss Cum.	Miles/Mil Per.	Cum.	Worn Est Per Cum to
1000				
1010				
1020				
1030	8.21	9.1	-	17.2
1040				
1050	18.21	7.1	8.0	22.8
1060				
1070				
1080				
1090	20.46	6.5	7.4	24.9
1100				
1110				
1120				
1130				
1140				
1150				
1160				
1170				
1180				
1190				
1200				
1210				
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4930				

TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128HS

Project 20-1-110

Tire Group A-3

Mfg. Descr. Firestone Super Ground Grip

Goer H.D.

Control

Date Feb-

1963 Tire Size 29.5-25

P.R. 16

Ribs Lug Type

paig

Rotation

Yeh-Veh. ea. 2500

Fig. X 25 5000

Pos.	Meas. Miles		Loss	0	1st	2nd	3rd	Profile	Dur. "A"	Orig. Tread		Depth		Tread Loss		Mils. V-6	Mils. & Loss		Miles/Mil Per.	Worn Per. Cum.	Est. Mi. to Bald
	Per.	Cum.								V-1	V-2	V-3	V-4	V-5	Per.		Cum.				
LR	2520	2520		74.11	30.79			57	1.563	1.500	1.861										
C-1				73.91	30.74			57	1.475	1.399	1.065										
				-0.2	-0.2				0.088	0.101	0.496								8.6	187	
LR	2502	5022		73.53	30.83			58	1.128	1.249	0.250										
C-3				-0.1	0.1				0.347	0.180	0.815								4.3	5.8	372.552
RF	2500	7527		74.25	31.07			55	425	1046	0.150										
C-2				9.2	0.9				708	703	2820								5.1	5.5	315.814
RF	2500	10022		74.07	31.16			56	070	813	WA										
C-1				-(0.08)	1.2				358	533	-										

TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128HS

Project 20-1-110 Tire Group B-1 Mfg. Descr. U.S. Royal Tactical M.S. Rotation Voids 1.3

Date Feb. 1963 Tire Size 29.5-25 P.R. 16 Ribs Lug Type Mileage & Loss Mileage & Loss Miles/Mil. Worn Est Mi. Per Cum to Bald

Pos.	Meas.	Miles	Lb/Cu	0.04	X Sec	Profile	Sur.	Orig.	Tread	Depth	Tread	Loss	Mileage	Miles/Mil.	Worn Est
ar.	Per.	Cum.	Loss	Inc	Inc	Per.	"A"	V-1	V-2	V-3	V-4	V-5	Per.	Cum.	Per Cum to Bald
B-1	LF	0.19	73.22	31.85		54	1.314	1.335					2649		
C-2		2520	73.71	32.24		54	1.226	1.234					2460		
				1.2			0.088	0.101					189	26.6	7.1
LF	2502	5022	73.60	32.32		56	1.128	1.134					2332		
C-1				1.5			0.028	0.100					128	39.1	48.11.9
RR	2209	7231	73.77	31.88		56	1.164	1.047					2211		
C-3				0.1			34	87					121	43.8	44.46.5
RR	2793		74.04	31.02		62	1.332	1.333					2665		
C-2				1.8		56	1.170	1.116					2286		
RR	2503	5296	73.87	31.41		56	972	982					379	13.3	14.214.2
C-1				1.3			198	134					1954		
RR	216	5512		-		58	916.0	891.0					337	15.1	14.9 12.526.7
C-3				-			050.0	091.0					-	-	-

Outside EX 1808

36

GR 1177

Form 1041-SS

Rotation	Veh. to ven. ca.
Figs X	ca. 2500
	ca. 5000

Pos.	Meas. Miles	Lb/Cum Loss	O.D. X Sec		Profile Low	Dur. "A"	Orig. Tread Depth		Tread Loss		Miles & Loss Cum.	Miles/Mil		Horn Est. Mi. Per. Cum. to 1000
			Inc	Inc			V-1	V-2	V-3	V-4		V-5	V-6	
RP	0-1		73.98	31.84		58	1.363	1.339			2702			
C-2	2520	2520	73.80	31.84		54	1.306	1.245			2551			
RP	2502	5022	73.70	32.00		56	1.222	1.128			2350			
C-1				0.5			0.084	0.117			201	24.9	28.5	7.4
LF	2476	7498	73.65	32.35		56	1.164	1.047			2211			
C-3				1.6			0.58	0.81			139	35.6	30.5	5.1
LF	2526	10024	73.55	32.27		56	1.126	0.99			2125			
C-2				1.4			0.38	0.48			086	58.7	34.7	5.2
LF	2503	12527	73.58	32.02		56	1.058	0.88			1946			
C-1				0.6			0.68	1.11			179	28.0	33.1	6.6
LF	779	13306	-	-		58	0.58	0.24			-	-	-	-
C-1				-			1.08	0.64			-	-	-	-
TEST TERMINATED 6/5/63														
(1) MEASUREMENTS WERE TAKEN ON UNMOUNTED TIRES														

STABY 8:03

Mr. Deane

Firestone

५७५

DECLARATION

101

5A02Y

Mar to Feb.

Time Size 29.5-3

• 1988 • 91

[illegible]

10

ASAP

...

[illegible]

[illegible]

For: 128MS

Super Group 2000

Box	Folder	Item	Type
16	16	16	16

Dealing with

veh. to veh. 22. 2' 30"

[illegible]

Voids 12.2

Miles Sec.	Loss Cum.	Miles/Mil Per. Cum.	Horn Per Cum
40			
41			
42	115	18.3	189
43			
44	874	16.1	17.1
45			10.5
46			189
47			
48	1712	17.5	15.3
49			17.9
50			318
51			
52	2096	12.1	14.3
53			13.3
54			452
55			
56	27	11.4	13.6
57			14.2
58			294
59			
60	185	18.5	14.5
61			WS
62			WS
63			WS
64			WS
65			WS
66			WS
67			WS
68			WS
69			WS
70			WS
71			WS
72			WS
73			WS
74			WS
75			WS
76			WS
77			WS
78			WS
79			WS
80			WS
81			WS
82			WS
83			WS
84			WS
85			WS
86			WS
87			WS
88			WS
89			WS
90			WS
91			WS
92			WS
93			WS
94			WS
95			WS
96			WS
97			WS
98			WS
99			WS
100			WS

TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 128MS

Project 20-1-110 Tire Group C-3

Mfg. Descr. Firestone Super Ground Grip Goer

Date Feb 1963 Tire Size 29.5-25 P.R. 16

Ribs Lugs Type

paig

Rotation Voids 1.3

Veh. to veh. ea. 2500

Eig. X ea. 5000

Code	Pos.	Meas.	Miles	Lb/Gal	0 Dr	K Sec	Profile	Sur. Orig.	Tread Depth			Miles	Mils. & Loss		Miles/Mil.	Worn	Est Mi.
									V-1	V-2	V-3		Per.	Cum.			
C-3	LR	Orig.						60	1.565	1.500	1.570		3135				
	C-3	2520	2520					62	1.538	1.373	1.810		2848				
LR									0.027	0.127	0.260		0.287	287	17.6	9.2	
	C-2	2502	5022					64	1.392	1.292	1.007		2399				
RF									0.146	0.081	0.303		0.449	736	11.1	13.6	14.3 28.5
	C-1	2500	7522					63	1.705	1.221	0.97		2107				
C-1									1.87	0.71	1.10		2.97	1033	14.8	14.6	9.5 330
	RF	2520	10022					64	0.97	1.093	0.31		1728				
C-3									3.08	1.28	0.66		3.74	1407	13.4	14.2	11.9 44.9
	RF	2503	12525					64	5.87	1.023	0.99		1286				
C-2									3.10	0.70	1.32		4.42	1849	11.3	13.5	14.1 530
	RF	2515	15040					64	4.22	0.93	5.41		963				
C-1									1.65	0.90	1.58		323	2172	15.6	13.8	10.3 61.3
TEST TERMINATED 6-1-63																	

Outside X 29 500-3

voids 1, 2, 3

[illegible]

Form 1040-1

Mfg. Deser. U.S. Royal Tactical M.S.

Tire Group C-4

1963	Tire Size	29.5 - 25	P.R.	16	Ribs	Load Type

D918

Don't

veh. to veh. ca. 2500
F19 X ca. 5000

Code	Pos.	Meas. Miles		Loss	O.D. X Sec	Profile	Dur. "A"	Tread Depth & Tread Loss, Mile						Miles & Loss		Miles/Mil		Horn Per Cum to Bald	Est Mi.
		RR	C-3					V-1	V-2	V-3	V-4	V-5	V-6	Per.	Cum.	Per.	Cum.		
C-4	RR	2500	2520		73.62 30.40		60	1570	1600	1560			3330						
	C-3				73.75 30.56		63	1470	1873	1455			2925						
	RR	2502	5022		0.2 0.5			0.100	0.127	105			205	205	24.6	-	65	-	
	C-2				73.90 30.58		65	1282	1325	1150			2432						
					0.4 0.6			0.188	0.048	305			493	698	10.2	14.4	154	223	
	LF	2500	7522		74.28 30.86		64	1042	1262	1023			2065						
	C-1				0.8 1.5			240	73	127			367	1065	13.6	14.1	117	340	
	LF	2500	10022		74.17 30.86		65	818	1195	911			1729						
	C-3				0.7 1.5			224	057	112			336	1401	14.9	14.3	10.7	448	
	LF	2503	12525		73.99 30.84		62	569	1108	806			1375						
	C-2				0.5 1.4			249	087	105			354	1755	14.1	14.3	11.3	561	
	LF	2515	15040		74.19 30.94		63	346	1.014	709			1055						
	C-1				0.8 1.8			223	094	097			320	2075	15.7	14.5	10.3	665	
	TEST TERMINATED 6-11-63																		

Voids 1,2,3			
Miles & Loss	Miles/Mil	Morn	
Per. Cum.	Per. Cum.	Per. Cum.	Per. Cum.
4660			
4298			
367	332	22.8	72
3757			
541	813	13.9	17.8
3351			
440	1318	17.0	17.7
2924			
393	1706	19.1	17.6
2483			
411	2147	17.0	17.5
2061			
414	2561	18.2	17.6
			89.553

SECRET

[illegible][illegible]

[illegible]

TIME CONDITION & SUMMARY

HODGES TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110

Tire Group A-2

Mfr. Descrip. Firestone Super Ground Grip

Control

Date Feb, 1963

Tire Size 295-25

P.R. 16

Ribs Lugs Type

psig

Rotation Veh. to Veh. ea 2500

Flux 44 4600

Id Pos. Miles	Fold Cracks	U F	SL	S F	T B T	Scuff	I V	T S	F V	F S	Other
2 RF 2520							M Ins		M Toe		
C-1 2-26							Out		Se Heel		
2624									In + Out		M wipe In & Out shoulder
2-28											
RF 5022							M Out		M Out		
C-3 3-15							Se In		Se In		
LB 7572	1 1/4 x 1 1/2" TE 2" to						M crown		Se In		SE RUBBING OFF LUGS IN
C-2 3-30	entire as 9										CRACKED & BROKEN AREA
LR 10022	1 1/4 x 3/4 TF Yes						M Heel		Se In 2 in		TF Outside shoulder
C-1 4-16	4" to inside of crown						In crown				5 1/2 x 2" thru 2 breakers
											2 1/2 x 1 1/4 thru 1 breaker
											1 1/2 x 1 Fabric exposed
											Se wiping In & Out, Tie
											REMOVED FROM TEST
											DUE TO BOTH SHOULDERS
											WORN SMOOTH

Fold B-Hib A-11 CO-Chunkout WA-Worn Any TP-To, MTP-Not to Fabric. V8-Very slight S-slight N-Noting Se-Severe. UT-Undertear
 S-Side Lift ST-Side Tear SET-Side End Tear TBT-Tie Bar Tear IT-Irregular Wear TS-Tread Splice TW-Tear Wear FS-Flat Spot
 Hs-Heel To Toe Vehicles = C-1, C-2, C-3. In=Inside Shoulder Out= Outside Shoulder

5-28-64

Proj. # 20-1-110 Tire Group A-3 Mfr. Descrp. Firestone Super Ground Grip H.D. Control
Date Feb. 1943 Tire size 2.5-2.5 P.R. 16 Ribs LINE Type _____ _____ _____ _____
Rotation _____ Veh. to Veh. ca 2500
File # ca. 8000

[illegible]

TITLE

W-Heel Y-Toe Vehicles = C-1, C-2, C-3 In = Inside Shoulder Out = Outside Shoulder.

TIME CONDITION & SUMMARY

MOOGES TRANSPORTATION INC.

Form # 128-C

Control

Firestone Super Ground Grip Goer H.D.

1953 Tire Size 29.5-25 P.R. 16

Ribs Lug Type

Notation Veh to Veh ea. 2500

Fig. X ea 2500

Pos.	Miles	Void Cracks	UT	SL	ST	TBT	Scuff	IW	TS	FW	FS	Other
RR 2520								M In +		SA heel		
C-1 2-26								Out		M Toe		
2624										IN-OUT		M Wipe In & Out
2-20												
RR 5022								Se In		SA heel		M Wipe In - Out
C-3 3-15								& Out		IN-OUT		
LF 17522								SE IN-OUT		SE HEEL		SE WIPING OF LUGS IN CENTER GROOVED AREA
C-2 3-30								IN-OUT		IN-OUT		
LF 10022								M across		Se In &		Se Wiping In & Out
C-1 4-16								tread		out		TIRE GROUP REMOVED FROM TEST DUE TO THREE OF THE FOUR TIRES WORN SMOOTH.

fold R-Rib A-All CO-Chalkout MA-Worn Away TP-To, WTP-Not To Fabric. VS-Very Slight S-Slight N-Medium Se-Severe. UT-Under-tear S-Side Lift ST-Side Tear SST-Side End Tear TBT-Tie Bar Tear IW-Irregular Wear TS-Tread Splice FW-Fast Wear FS-Flat Spot H=Heel T=Toe. Vehicles C-1, C-2, C-3 In= Inside Shoulder Out= Outside Shoulder.

TIRE CONDITION & SUMMARY

MOORE TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110 Tire Group B-2 Mfr. Descrip. U.S. Royal Sapirol M-3, Rotation Vch. to Veh. eq 2500
 Date Feb. 12/3 Tire Size 295-25 P.R. 16 Ribs Type 16

Pos. / Flies	Vald Cracks	UT	SL	ST	TBT	Scuff	IV	TS	FV	FS	Other
RF 2520									VS Heel		1" 3 1/2" @ 4 1/2" circum.
C-2 2-20									In		side wall splice openings
											outer, above bead, NTF
											1/2" circum. sidewall
											splice opening, inner
											above bead, NTF
RF 5022							S In.	S out	VS Heel		Fold openings, outside
C-1 3-15							VS out		S In.		1-2" 1-6 1/4" 1-8 1/2"
											F.O. inside 1-1/2" NTF
LR 7020							S out	S out	M In		End openings, outside
C-3 3-20									1/2 out		1-1" 1-1 1/2" 1-8" 1-10" TP
											F.O. inside 1-1/2" NTF
											1/4" X 3/8" RADIAL CRACK
											IN OUTSIDE SIDEWALL TE.
											ONE AREA OF SWELLING
											ON INSIDE SIDEWALL
LR 10024							S across	M heel out			Radial cracks, inside sidewall
C-2 4-16							Tread	B heel In			18" up from flange, 1 1/2" X 1 1/2"
											three wire plies, cords exposed
											11" up from flange, 1" X 1/4"
											1/2 X 1/2, three wire plies
											12 1/2" up from flange, 1 1/2" X 1/2"
											three wire plies, cords exposed
											cut 1 1/2 X 1/2 three wire plies
											cords exposed
											Fold opening, inside 1 1/2"
											Break above bead, 1" TP
											Fold opening, outside
											2 1/2 X 3/4, 2 1/2 X 1/4 TP
											1 X 1/2 NTF
Radial crack from flange base							3/4" wide	w/3/8" cracks extending parallel			
to flange											
Radial crack 1 1/4 X 3/4 deep											

Id R-Rib A-All CO-Chamout M-More Any TP-To, RTT-Rot To Fabric. VS-Very Slight S-Slight N-Medium So-Severe. UT-Undercar
 lipse Lift ST-Slope Tread SET-Slope End Tear TBT-Tile Bar Tear IV-Irregular Near TS-Tread Splice FU-Fast Near FS-Flat Spot
 u-Heel Tz-Tac Vehicles = C-1, C-2, C-3 In=Inside Shoulder, Out = Outside shoulder.

THE CHURCH & DWIGHT

NOTES INVESTIGATION INC.

Page 0 128-C

Prof. 20-1-110
Date 20-1-110

Place Group B. WSP. Group. U.S. Royal Tactical M.S.
Time 20-1-110 P.M. 16. 1100 Inc. Type

Retention

Pos. Miles	Wid Creek	UT	SL	SY	YBT	Griff	YB	YS	FV	FS	Other
2 LE 10876											Failed from 2.75"
(C-1) 5-20							M-N-Q	M.A.			Radial crack through
							S-H-14				inside sidewall and
											1.25" crack in liner
											Other in S.W. End
											Cracks
											1.25 x .025" D
											.075 x .025" D
											2.25 x .050" D
											2.00 x .050" D
											.075 x .025" D
											Fold openings above
											inside heads
											1.00' x .050" D
											.050' x .050" D
											Fold openings above
											outside heads
											22.00" to fabric
											11.00" to fabric
											through several pieces
											this weld opening
											developed into
											connected radial
											and circum. crack

For: 128-C

Date	Tire	Size	P.R.	Type	Rotation
Feb.	1963	29.5-25	16	Lugs	psig
				Ribs	
					Veh. to veh. ca 2500

[illegible]

A-All CO-Chunkout WA-Worn Away TP-Toe, WTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Underwear
Lst ST-Stripe Tear SST-Side End Tear TST-Tie Bar Tear IW-Irregular Wear TS-Tread Splice FW-Fast Wear FS-Flat Spot
H=Heel T=Toe Vehicles = C-1,C-2, C-3 In=Inside shoulder, Out=outside shoulder.

TIME CONDITION & SUMMARY

MOORE TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110
 Tire Group B-4
 Mfg. Descrip. U.S. Royal Tactical M.S.
 Date Feb. 1963
 Tire Size 28.5-23
 P.R. 16
 Ribs Lug Type
 Rotation Veh. to Veh. ea. 2500
 Fig. 2 ea. 1000

Pos.	Miles	Vold Cracks	UT	SL	ST	TST	Scuff	IV	TS	PV	FS	Other
RR 2820										VS Heel		Tread Lug Repairs Noted.
C-2 226										ln.		1-1/4" 1-1/2" circumfer-
												ential tread splice
												opening, outer above
												bead NTF
												Several bulged areas
												inside & out. sidewall
												Fold opening, defective
												repair.
RR 5022												80% of fold splice
C-1 3-18										M H ln.		open inside. Same as
												above outside.
LF 7498												FOLD OPENINGS OUTSIDE.
C-3 3-20												2-1/2" x 3/8" NTF, 1-2" x 1/4"
												NTF, 1-2" x 1/2" TF & 1-5"
												1/2" TF. 1/2" TREAD LUG
												PERMANENT DAMAGE. FOLDING
												FLAP ON INSIDE CHANGING
												OFF. FLANGE SCREWING
												INSIDE ABOVE BEAD
												TOTAL CIRCUMFERENCE.
												TREAD ABOVE OF SUELLING
												ON INSIDE SIDEWALL AND
												TREAD AREAS ON OUTSIDE
												SIDEWALL APPROX. 2/3
												LARGER THAN NORMAL
												SIDEWALL PROFILE.
LF 10028												Lug repair cracked at base
C-2 4-16										M to Se		2 3/4" x 1/2" Chaffer strip
										heel ln		lifting entire circumfer-
										M Heel		ence, inside. M chafing
										cut		in area.

Id R-Rib A-All CO-Chunkout Wd-Worn Away TT-To, TTT-Flat to Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undertear
 Ipe Lift ST-Slip Tear SST-Slip End Tear TST-Tire Bar Tear IV-Irregular Wear TS-Tread Splice PV-Fast Wear FS-Flat Spot
 M=Heel T=Toe Vehicles = C-1, C-2, C-3 ln=inside shoulder, cut = outside shoulder

Form 1285

page.

[illegible]

Void R-Rib A-All CO-Chunkout WA-Worn Away TP-To, NTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Underwear
L-Slice Lift ST-Slice Tear SET-Slice End Tear TBT-Tie Bar Tear IN-Irregular Wear T8-Tread Splice FV-Fast Wear F8-Flat Spot

12-12-67

Rotation Year: 1991-1992

Weld R-Rib A-All CO-Checkout WA-Worn Army TP-To, WTF-Not To Fabric. V8-Very Slight 8-Slight M-Medium Se-Severe. UT-Underwear
S-Side Lift ST-Slips Tear SET-Slips End Tear TBT-Tie Bar Tear IV-Irregular Wear T8-Tread Splice FW-Fast Wear F8-Flat Spot
H=HEEL T=Toe JEWELERS=C-1, C-2, C-3 IN=INSIDE SHOULDER OUT=OUTSIDE SHOULDER

1004 5-15-57

Notation $\mathbb{N} = \{1, 2, 3, \dots\}$
 $\mathbb{Z} = \{\dots, -2, -1, 0, 1, 2, \dots\}$
 $\mathbb{Q} = \{\text{rational numbers}\}$
 $\mathbb{R} = \{\text{real numbers}\}$
 $\mathbb{C} = \{\text{complex numbers}\}$

[illegible]

**-Void R-Rib A-All CO-Chunkout WA-Worn Away TP-To, WTT-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Underwear
-S-Side Lift ST-Side Tear SET-Side End Tear TBT-Tie Bar Tear IW-Irregular Wear TS-Tread Splice FW-Fast Wear F8-Flat Spot**

H=HEEL T=TOE V=VARIABLES=C-1,C-2,C-3
IN=INSIDE SHOULDER OUT=OUTSIDE SHOULDER

TIRE CONDITION & SERVICE

MOORE TRANSPORTATION INC.

Form 1 108-C

Proj. # 20-1-110

Tire Group C-1 Mfg. Descrip. Firestone Super Grand Grip Clear

Date Feb-

1963 Tire Size 29.9-25 P.R. 16 Ribs Lugz Type

note

Rotation Mark to Vnt. ea. 2,500 Miles

Code	Pos.	Miles	Void Cracks	UT	SB	ST	TBT	Scuff	IF	TS	PV	FS	Other
C-1	LF	2520									VS Heel		VS Ribbed Out
	C-3	2-26									out		VS Ribbed Out
		2624									3 in		VS Wipe out Scarps In.
	LF	5022							S out		3 Heel		5 Ribbed Delamination
	C-2	3-15							M in		M H&T		Same as above.
											III		
	RR	1523							M in		M in		M in
	C-1	3-30											Center Scarps Area
													in 4 out. VS Ribbed
													Delamination in Ribbed
													Wearing Away on Wires
	RR	10023							M across		3c in 6		3c Wipe in 6 out
	C-3	4-16							Heel		out		VS Ribbed delamination
									6 crown				
	RR	12525											
	C-2	5-29							SAME		SAME		SAME
	RR	15040							SAME		SAME		3c Wipe in 6 out
	C-1	6-11							SEV. Heel				31. Ribbed Delamination
									WEAR IN				CROWN LUGS TEARING
									CROWN				AT PRESSURE POINT
													BEAD OK. LINER OK.

Void R-Rib A-All CO-Chunkout MA-Worn Away TP-To, HTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undertone
 S-Side Lift ST-Side Tear SET-Side End Tear TBT-Tie Bar Tear IR-Irregular Wear TS-Tread Splice TW-Tear FS-Flat Spot
 H=Heel T=Toe Vehicles z G-1, C-2, C-3. In=Inside shoulder, Out=Outside, shoulder.

Outside K 25500-5

TIME CONDITION & SUMMARY

MODES TRANSPORTATION INC.

Form # 128-C

Proj. # 20-1-110 Tire Group C-2 Mfr. Descr. Firestone Super Ground Grip Gser.
 Date Feb. 1973 Tire Size 22.5-25 P.R. 16 Ribs Lugs Type psig. Rotation Veh. to Veh. ca 2500
 Fig X ca 5000

do	Pos.	Miles	Vold Cracks	UT	SL	ST	TBT	Scuff	IW	TS	PW	FS	Other
P-2	RF	2520	1 3/4" x 1 1/2"	Yes @ base							M heel out		S wipe in. M wipe out.
	C-3	2-26		center lug							S heel in		V5 ribbon delamination
	RF	5022	5" TF	Yes					M in & out				S wipe in. M wipe out.
	C-2	3-13	6" TF	Yes					Out				V5 ribbon delamination
	RF	5022	5" TF	Yes					M in & out				V5 ribbon delamination
	C-2	3-15	6" TF	Yes							S Tag		V5 ribbon delamination
											M heel in & out		
	LR	7522	7" TF	Yes 1 1/2"					M in-out		M H in		S WIPING IN & M WIPING
	C-1	2-30	7 1/4" TF	Yes 1 1/2"					S in		S H out		OUT AT CENTER GROOVE
									turning		S H in		ARMA. S. RIBBON DELAMINATION
													TION.
	LR	10022	8 1/4" x 1/2" TF	Yes 1 3/4					M across tire		S e out		SI Ribbon delamination
	C-3	4-16	7 3/4" x 1/2" Thru top breaker	Yes 1 3/4							M in		S e wipe in & out
			4 1/2" x 1/2" TF	Yes 1/4							SI crown		Cut 3 x 3/8 NTF
	LR	12525	9 1/4" x 2 1/2" Thru in 4	"									
	C-2	5-29	9 1/2" x 2 1/2"	"									
			7 1/2" x 1 1/2" T	"									
			5 1/4" x 1 1/4"										
			2 3/4" x 3/4" TF										
			2 3/4" x 3/4" TF										
	LR	15040	10" x 3 1/4"	Yes	Thru outer plies				S e v. wear		S e v. in		S e. Wipe in & out
	C-1	6-11	12" x 4"	Yes	" SIX PLYS				WEAR IN		S e out		SI Ribbon Delamin.
			9" x 1 3/4"	Yes	" TWO PLYS				CROWN				CROWN LUGS TEARING
			5" x 1"	Yes	" ONE PLY								AT PRESSURE FRINT
			3 1/2" x 3/4" TF	Yes									BEAD O.K. LINER O.K.
			5 1/2" x 1 1/2"	Yes	Thru ONE PLY								TIRE REMOVED FROM TIRE
			2 1/2" x 1 1/4" NTF	NO									DUE TO OUTSIDE SHOULD
													WHEEL SMOOTH.

Vold R-Rib A-All CO-Chunkout MA-More Any TP-To, NTF-Not To Fabric. V8-Very Slight S-Slight M-Medium Se-Severe. UT-Undercar
 -Sipe Left ST-Sipe Tear ST-Sipe End Tear TBT-Tie Bar Tear IN-Irregular Wear TS-Tread Splice FW-Fast Wear FS-Flat Spot

Wz Wear T=Toe Vehicles = C-1, C-2, C-3. In= Inside Shoulder Out = outside shoulder.

TIME CONDITION & SUMMARY

MODES TRANSPORTATION INC.

Form 128-C

Proj. # 20-1-110 Tire Group C-3 Mfg. Decrip. Firestone Super Ground Grip Cleer
 Date Feb. 1963 Tire Size 22.5-25 P.R. 16 Ribs Type Lugs Type Rotation Veh. to veh. ea. 2500
 Fig. X 44. H000

Pos.	Miles	Void Cracks	UT	SL	S.T	T.B.T	Scuff	I.W	T.S	P.W	F.S	Other
LR 2520										VS H out		Void-type ribbon surface
C-3 2-26										S H & T		separations 3/8" to 1/2" wide
										in.		around circumference
2624												VS wipe out M wipe in.
												S ribbon delamination
LR 5022								S out		S H & T		
C-2 2-16								M in		out		M ribbon delamination
										M H & T		
										in		
RF 1522								M H out				M wipe in & VS wipe out
C-1 2-10								S H in				out of lugs at center
												grooved areas. M ribbon
												delamination
RF 10022		2 x 3/16 NTF in						M heel		S e in		S e wipe in. M wipe out
C-3 4-14	4 x 1/2 TF out	Yes						tread		out		M Ribbon delamination
	6 x 1/2 TF in	Yes 3/4										
RF 12525	3 1/2 x 1/4 TF	Yes										
C-2 5-24	3 x 1/4 TF	Yes								SAME		SAME
	4 1/4 x 1/2 NTF	Yes										2 1/4 x 3/4" GAB NTF
	7" x 1" TF	Yes										4 1/2 x 1 1/4 "
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										
RF 15025	3 1/2 x 1/4 TF	Yes										
C-1 6-11	1 1/2 x 1/4 TF	Yes										
	3 1/2 x 1/2 TF	Yes										
	3 x 1/2 TF	Yes										
	3 1/2 x 1/4 NTF	No										
	1 1/2 x 1/2 TF	Yes										
	1 1/2 x 1/2 TF	Yes										
	2 1/2 x 1/2 TF	No										

1

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[illegible]

TF-To, WTP-Not To Fabric. V9-Very Slight S-Slight H-Medium Se-Revers. UT-Underwear
 WA-Warn Away A-All CO-Chambray
 R-Rib B-Bottom L-Lift S-Side Tear SET-Side End Tear TBT-Tie Bar Tear IV-Irregular Weave
 TIT-Tread Splice TIV-Fast Weave TB-Flat Spot

TIRE CONDITION & SUMMARY

ARMED TRANSPORTATION INC.

Form # 123-E

Proj. # 20-1-110
Date Feb

Tire Group 5
Tire Size 29.5-25 P.R. 16

USG, Deserip. J.S. DIRECTIONAL RADIAL - RADIAL DAY CONSTRUCTION
29.5-25 P.R. 16 Ribs Lug. Type

page 2 of 2 Notation

Code	Pos.	Miles	Void Cracks	UT	SL	ST	TST	Scuff	IV	FS	FW	FS	Other
1-1	-	0-16									S-H-AU		USED TIRE. SLUG
		6-4									LUCA		CHIPPING. 2 1/2" RADIAL
													CRACK 0.100" IN DEPTH
													NITE INSIDE SIDEWALL
													CIRCUMFERENTIAL FLAW
													CRACKS ABOVE BEAD
													CRACKS ABOVE BEAD
													SHALLOW CUTTING ON
													LUCA
LR	2041										M-H-M		2 1/2" x 1/2" CUT IN VOID
C-3	6-18										1 CUT		INSIDE. SHALLOW CUTTING
											S-H-M		ON LUCA. 9 1/4" X 0.150"
													RADIAL CRACK SITE INSIDE
													SIDEWALL. 7 1/2" X 0.100"
													RADIAL CRACK NITE INSIDE
													BEWALL. CIRCUMFERENTIAL
													FLAW CRACKS ABOVE BEAD
													OUTSIDE SIDEWALL
-	-	0-16									S-H-AU		USED TIRE. HED LUG
		6-4									LUCA		CHIPPING AND TEARING.
													SL CRACK CRACKING
													ACROSS TREAD. SL FLAW
													CRACKING ABOVE BEAD
													INSIDE SIDEWALL
RR	2041										SL H-M		MED LUG CHIPPING AND
C-3	6-18										M H M		TEARING. 2 1/2" X 0.100"
											M H M		RADIAL CRACK NITE
													INSIDE SHOULDER. SL FLAW
													CRACKING INSIDE & OUTSIDE
													SIDEWALL. SL CRACK
													CRACKING ACROSS TREAD

Void R-Rib A-ALL CO-Chunkout UA-Worn Away TP-To, NTP-Not To Fabric. VS-Very Slight S-Slight M-Medium Se-Severe. UT-Undercarriage
-Sipe Lift ST-Sipe Tear SST-Sipe End Tear TST-Tie Bar Tear IV-Irregular Wear TS-Tread Splice FW-Past Wear FS-Flat Spot

Best Available Copy

PLST DATA (Contd.)

3. Tread Temperature and Tire Pressures

Original Pavement Course Operation (10+ miles per shift)

Tire Group	C	D
Vehicle	C-1	C-2
Date	2/27/63	2/27/63
Miles	2773	2773
Ambient	49°F	
Pavement	--	

	C		D	
	Start	Temp. Inc	Start	Temp. Inc
LF	--	--	--	--
RF	--	--	--	--
Avg. Front	--	--	--	--
LP	25.0	33.0	25.0	33.0
RR	25.0	33.0	25.0	33.0
Avg. Rear	25.0	33.0	25.0	33.0
Avg. Group	--	--	--	--
2/28/63				
Date	2/28/63			
Miles	2870			
Ambient	50°F			
Pavement	68°F			
LF	36.0	47.0	36.0	47.0
RF	36.0	47.0	36.0	47.0
Avg. Front	36.0	47.0	36.0	47.0
LP	25.0	34.0	25.0	34.0
RR	26.0	35.0	26.0	35.0
Avg. Rear	26.0	35.0	26.0	35.0
Avg. Group	31.0	41.0	31.0	41.0

	C-1		C-2	
	Start	Temp. Inc	Start	Temp. Inc
B-1	40.5	51.5	40.5	51.5
B-2	40.5	51.5	40.5	51.5
B-3	26.0	34.5	26.0	34.5
B-4	26.0	35.0	26.0	35.0
Avg. Group	33.0	43.0	33.0	43.0

	C-1		C-2	
	Start	Temp. Inc	Start	Temp. Inc
B-1	40.5	51.5	40.5	51.5
B-2	40.5	51.5	40.5	51.5
B-3	26.0	34.5	26.0	34.5
B-4	26.0	35.0	26.0	35.0
Avg. Group	33.0	43.0	33.0	43.0

TEST DATA (Contd.)

3. Tread Temperature and Tire Pressures (Contd.)

Original Pavement Course Operation (104 miles per shift) (Contd.)

Tire Group	A			B			C				
	Start	Temp	Inc	Start	Temp	Inc	Start	Temp	Inc		
Vehicle	C-3			C-1			C-2				
Date	3/1/63(1)			3/1/63(2)			3/1/63(1)				
Miles	3121			3121			3121				
Ambient	55°F										
Pavement	69°F										
	LF	A-1	36.0	51.0	15.0	177	B-1	41.0	51.5	10.5	185
	RF	A-2	36.0	51.5	15.5	175	B-2	41.0	51.0	10.0	185
	Avg. Front		36.0	51.5	15.5	176		41.0	51.5	10.5	185
	LR	A-3	26.0	39.0	13.0	195	B-3	26.0	35.0	9.0	165
	RR	A-4	26.0	39.0	13.0	190	B-4	26.0	37.0	11.0	165
	Avg. Rear		26.0	39.0	13.0	193		26.0	36.0	10.0	165
	Avg. Group		31.0	45.0	14.0	184		34.0	44.0	10.0	175
Date	3/8/63(1)			3/8/63(2)			3/8/63(1)				
Miles	4399			4399			4399				
Ambient	54°F										
Pavement	68°F										
	LF	A-1	35.0	47.5	12.5	190	B-1	40.0	51.0	11.0	210
	RF	A-2	35.0	49.0	14.0	183	B-2	40.0	51.5	11.5	205
	Avg. Front		35.0	48.0	13.0	187		40.0	51.5	11.5	208
	LR	A-3	25.0	35.5	10.5	192	B-3	25.0	34.0	9.0	174
	RR	A-4	25.0	35.0	10.0	183	B-4	25.0	37.0	12.0	160
	Avg. Rear		25.0	35.5	10.5	188		25.0	36.0	11.0	167
	Avg. Group		30.0	42.0	12.0	187		32.5	43.5	11.0	187
	LF							40.0	54.0	14.0	185
	RF							40.0	54.5	14.5	192
	Avg. Front							40.0	54.5	14.5	189
	LR							30.0	41.0	11.0	178
	RR							30.0	41.5	11.5	180
	Avg. Rear							30.0	41.5	11.5	179
	Avg. Group							35.0	48.0	13.0	184

(1) Taken 9" from crown center.

(2) Taken 10 1/2" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures

Revised Pavement Course Operation (194 miles per shift)

Tire Group	A			B			C		
	Start	psig	of Temp	Start	psig	of Temp	Start	psig	of Temp
Vehicle									
Date	3/19/63*	C-2		3/19/63**	C-3		3/19/63*	C-1	
Miles	5611			5611			5611		
Ambient	60°F								
Pavement	78°F								
LF	A-4	35.0	49.0	14.0	192		40.0	55.0	15.0
RF	A-3	35.0	50.0	15.0	200		40.0	55.0	15.0
Avg. Front		35.0	49.5	14.5	196		40.0	55.0	15.0
LR	A-2	25.0	37.5	12.5	175		30.0	40.0	10.0
RR	A-1	25.0	38.0	13.0	190		30.0	43.0	13.0
Avg. Rear		25.0	38.0	13.0	183		30.0	41.5	11.5
Avg. Group		30.0	43.5	13.5	189		35.0	48.0	13.0
Date	3/21/63*			3/21/63**			3/21/63*		
Miles	6029			6029					
Ambient	64°F								
Pavement	72°F								
LF	A-4	35.0	50.0	15.0	230		41.0	58.0	17.0
RF	A-3	35.0	50.5	15.5	220		41.0	58.0	17.0
Avg. Front		35.0	50.5	15.5	225		41.0	58.0	17.0
LR	A-2	26.0	38.5	12.5	190		31.0	44.0	13.0
RR	A-1	26.0	37.0	11.0	196		31.0	46.0	15.0
Avg. Rear		26.0	38.0	12.0	193		31.0	45.0	14.0
Avg. Group		30.5	44.0	13.5	209		36.0	51.5	15.5

(1) Tire had one area of 265°F.

(2) Tire had one separated tread area at 275°F. Tire was removed at end of shift.

* Taken 9" from crown center.

** Taken 10 1/2" from crown center.

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	<u>A</u>	<u>B</u>	<u>C</u>
Vehicle	C-2	C-3	C-1
Date	3/25/63***	3/25/63**	3/25/63***
Miles	6408	6408	6408
Ambient	57°F		
Pavement	70°F		

		psig			of		psig			of					
		Start	Temp	Inc			Start	Temp	Inc		Start	Temp	Inc		
LF	A-4	35.0	48.5	13.5	--	B-4	40.0	53.0	13.0	175	C-4	40.0	56.0	16.0	--
RF	A-3	35.0	49.5	14.5	205	B-5	40.0	52.0	12.0	180	C-3	40.0	56.5	16.5	195
Avg. Front		35.0	--	--	--		40.0	52.5	12.5	178		40.0	56.5	16.5	--
LR	A-2	25.0	37.0	12.0	--	B-2	25.0	35.5	10.5	--	C-2	30.0	42.5	12.5	--
RR	A-1	25.0	38.0	13.0	--	B-1	25.0	35.0	10.0	--	C-1	30.0	44.0	14.0	--
Avg. Rear		--	--	--	--		25.0	35.5	10.5	--		30.0	50.0	13.5	--
Avg. Group		--	--	--	--		--	--	--	--		35.0	50.0	15.0	--

Date	Miles	Ambient 64°F	Pavement 72°F
3/26/63***	6689		
3/26/63***	6689		
LF	A=4	35.0	50.0
RF	A=3	35.0	51.0
Avg. Front		35.0	50.5
LR	A=2	26.0	38.0
RR	A=1	26.0	39.0
Avg. Rear		26.0	38.5
Avg. Group		30.5	44.5
B-4	40.0	53.0	13.0
B-5	40.0	52.0	12.0
B-2	40.0	52.5	12.5
B-1	25.0	36.5	11.5
C-4	40.0	57.5	17.5
C-3	40.0	57.5	17.5
C-2	30.0	37.5	7.5
C-1	30.0	38.5	8.5
	30.0	38.0	8.0
	35.0	48.0	13.0

*** Taken 10 1/2" from crown center.
*** Taken 5 1/4" from crown center.

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A		B		C	
	Start	Temp	Start	Temp	Start	Temp
Vehicle	C-2		C-3		C-1	
Date	3/26/63***		3/26/63**		3/26/63***	
Miles	6717		6731		6745	
Ambient	66°F					
Pavement	77°F					

Date		3/26/63**	
Miles		6745	
Ambient	67°F		
Pavement	79°F		
LF	B-4	--	--
RF	B-5	--	--
Avg. Front		--	--
LR	B-2	--	185
RR	B-1	--	190(1)
Avg. Rear		--	188

*** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

(1) Tire had one area of 230-237°f (suspected separation). The same area 14 miles later recorded a temperature of 237°f. No separation developed.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Secondary Road Operation

Tire Group	A				B				C			
	Start	psig @ Temp	Inc	of Temp	Start	psig @ Temp	Inc	of Temp	Start	psig @ Temp	Inc	of Temp
Vehicle	C-2				C-3				C-1			
Date	3/27/63***				3/27/63**				3/27/63***			
Miles	6923				6923				6923			
Ambient	63°F											
Pavement	(1)											
LF	A-4	37.5	48.0	10.5 205	B-4	42.0	52.5	10.5 190	C-4	43.0	54.5	11.5 195
RF	A-3	37.5	47.5	10.0 202	B-5	42.0	50.5	8.5 180	C-3	43.0	54.5	11.5 195
Avg. Front	A-2	37.5	48.0	10.5 204		42.0	51.5	9.5 185		43.0	54.5	11.5 195
LR	A-2	28.0	38.0	10.0 195	B-2	27.5	35.0	7.5 180	C-2	31.5	41.5	10.0 185
RR	A-1	28.0	37.5	9.5 195	B-1	27.0	34.0	7.0 192(2)	C-1	31.5	42.0	10.5 180
Avg. Rear		28.0	38.0	10.0 195		27.0	34.5	7.5 186		31.5	42.0	10.5 183
Avg. Group		33.0	43.0	10.0 199		34.5	43.0	8.5 186		37.0	48.0	11.0 189

(1) Temperature taken this day were of secondary operation.

(2) Tire had one tread area of 2150F.

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

3. Tread Temperatures and Tire Pressures (Contd.)

Tire Group	A			B			C				
	Start	Temp	Inc	Start	Temp	Inc	Start	Temp	Inc		
Vehicle	C-1			C-2			C-3				
Date	4/4/63***			4/4/63**			4/4/63***				
Miles to Date	8106			8096			8135				
Ambient	60°F			60°F							
Pavement	70°F			75°F							
LF	A-4	36.0	48.0	12.0	195		B-4	41.0	53.0	12.0	205
RF	A-3	36.0	50.0	14.0	202		B-5	41.0	51.0	10.0	188
Avg. Front		--	--	--	199			--	--	--	185
LR	A-2	26.0	37.0	11.0	185		B-2	26.0	37.0	11.0	218
RR	A-1	26.0	37.0	11.0	185		B-6	26.0	36.0	10.0	205
Avg. Rear		--	--	--	185			--	--	--	212
Avg. Group		--	--	--	192			--	--	--	198
Date	4/4/63			4/4/63			4/4/63				
Miles to Date	8191			8139			8177				
Ambient	70°F										
Pavement	85°F										
LF	A-4	36.0	49.0	13.0	206		B-4	41.0	53.0	12.0	185
RF	A-3	36.0	50.0	14.0	220		B-5	41.0	51.5	10.5	185
Avg. Front		--	--	--	213			--	--	--	185
LR	A-2	26.0	38.5	12.5	210		B-2	26.0	37.5	11.5	212
RR	A-1	26.0	39.0	13.0	200		B-6	26.0	36.0	11.0	203
Avg. Rear		--	--	--	205			--	--	--	208
Avg. Group		--	--	--	209			--	--	--	196

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A			B			C		
	Vehicle	Date	Miles to Date	Ambient	Pavement	52°F	60°F	70°F	90°F
									</

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

		psig			of	psig			of	
		Start	Q	Temp		Start	Q	Temp		
	B-4	40.0	52.0	12.0	190	C-4	40.0	54.0	14.0	195
LF	B-5	40.0	51.0	11.0	185	C-3	40.0	55.0	15.0	200
RF		--	--	--	188		--	--	--	198
Avg. Front										
LR	B-2	25.0	36.5	11.5	200	C-2	25.0	43.0	18.0	205
RR	B-6	25.0	36.5	11.5	205(1)	C-1	25.0	45.0	20.0	195
Avg. Rear		--	--	--	203		--	--	--	200
Avg. Group		--	--	--	195		--	--	--	199

Date	Miles to Date	5/21/63	5/21/63
Ambient	10997	11072	1062
Pavement	82°F	84°F	83°F
	110°F	115°F	112°F

LF	B-4	40.0	52.0	12.0	193	C-4	40.0	55.0	15.0	220	D-4	40.0	52.0	12.0	225
RF	B-5	40.0	50.5	10.5	193	C-3	40.0	55.0	15.0	211	D-3	40.0	52.0	12.0	225
Avg. Front		--	--	--	193		--	--	--	216		--	--	--	225
LR	B-7	25.0	35.5	10.5	184	C-2	30.0	41.0	11.0	240	D-2	30.0	41.0	11.0	200
RR	B-6	25.0	36.0	11.0	265	C-1	30.0	43.0	13.0	200	D-1	30.0	42.0	12.0	205
Avg. Rear		--	--	--	225		--	--	--	220		--	--	--	203
Avg. Group		--	--	--	209		--	--	--	218		--	--	--	214

(1) Time had read sensation on inside shoulder which recorded a temperature of 255°F.

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	B			C			D							
	Vehicle	Date	Miles to Date	Ambient	Pavement	Start	Q	Temp	Start	Q	Temp	Start	Q	Temp
LF	B-4	40.0	52.0	12.0	215	C-4	40.0	54.0	14.0	205	D-4	40.0	50.0	10.0
RF	B-5	40.0	51.5	11.5	210	C-3	40.0	54.0	14.0	200	D-3	40.0	51.0	11.0
Avg. Front		--	--	--	213		--	--	--	203		--	--	212
LR	B-7	25.0	36.0	11.0	200	C-2	30.0	40.0	10.0	225	D-2	30.0	40.0	10.0
RR	B-6	25.0	36.5	11.5	265(1)	C-1	30.0	40.0	10.0	210	D-1	30.0	40.5	10.5
Avg. Rear		--	--	--	233		--	--	--	218		--	--	194
Avg. Group		--	--	--	223		--	--	--	210		--	--	203

(1) Tire separated around entire inside shoulder.

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift.) (Contd.)

Tire Group	C		D		E	
	Start	Temp	Start	Temp	Start	Temp
Vehicle	C-1		C-2		C-3	
Date	6/6/63		6/6/63		6/6/63	
Miles to Date	14189		3631		153	
Ambient	55°F		55°F		55°F	
Pavement	65°F		65°F		65°F	

	C		D		E	
	Start	Temp	Start	Temp	Start	Temp
LF	C-4	40.0	D-4	40.0	E-3	40.0
RF	C-3	40.0	D-3	40.0	E-4	40.0
Avg. Front		--		--		--
LR	C-2	30.0	D-2	30.0	E-1	30.0
PR	C-1	30.0	D-1	30.0	E-2	30.0
Avg. Rear		--		--		--
Avg. Group		--		--		--

	C		D		E	
	Start	Temp	Start	Temp	Start	Temp
LF	C-4	40.0	D-4	40.0	E-3	40.0
RF	C-3	40.0	D-3	40.0	E-4	40.0
Avg. Front		--		--		--
LR	C-2	30.0	D-2	30.0	E-1	30.0
PR	C-1	30.0	D-1	30.0	E-2	30.0
Avg. Rear		--		--		--
Avg. Group		--		--		--

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group
Vehicle
Date
Miles to Date
Ambient 68°F
Pavement 87°F

D
C-2
6/11/63
4708
E
C-3
6/11/63
1199

		psig			of	psig			of
		Start	Temp	Inc		Start	Temp	Inc	
LF	D-4	40.0	54.0	14.0	187	40.0	52.5	12.5	252
RF	D-3	40.0	53.5	13.5	192	40.0	52.0	12.0	225
Avg. Front		--	--	--	190	--	--	--	239
LR	D-2	30.0	41.0	11.0	203	30.0	38.0	8.0	234
RR	D-1	30.0	41.0	11.0	198	30.0	39.5	9.5	230
Avg. Rear		--	--	--	201	--	--	--	232
Avg. Group		--	--	--	195	--	--	--	235

Date
Miles to Date
Ambient 84°F
Pavement 97°F

6/12/63
4995
6/12/63
1635

LF	D-4	40.0	56.0	16.0	216	40.0	54.0	14.0	232
RF	D-3	40.0	55.0	15.0	212	40.0	53.0	13.0	242
Avg. Front		--	--	--	214	--	--	--	237
LR	D-2	30.0	43.0	13.0	215	30.0	40.0	10.0	256
RR	D-1	30.0	43.0	13.0	210	30.0	40.5	10.5	227
Avg. Rear		--	--	--	213	--	--	--	242
Avg. Group		--	--	--	213	--	--	--	239

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	D	E
Vehicle	C-1	C-3
Date	6/17/63	6/17/63
Miles to Date	5887	2487
Ambient	76°F	
Pavement	92°F	
	psig	psig
	Start	Start
	Temp	Temp
	Inc	Inc
	of	of
	Temp	Temp
LF	D-4	E-3
RF	D-3	E-4
Avg. Front		
LR	D-2	E-1
RR	D-1	E-2
Avg. Rear		
Avg. Group		

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FINAL REPORT

Project 20-1-110

Appendix A - "Ride" Study
and
Appendix B - Shallow Mud Traction

July 1963

Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada

APPENDIX A

FINAL REPORT

Project 20-1-110

Comparison of Vehicle "Ride"
as Influenced By Vehicle Configuration
and Tire Design

July 1963

Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada

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APPENDIX A

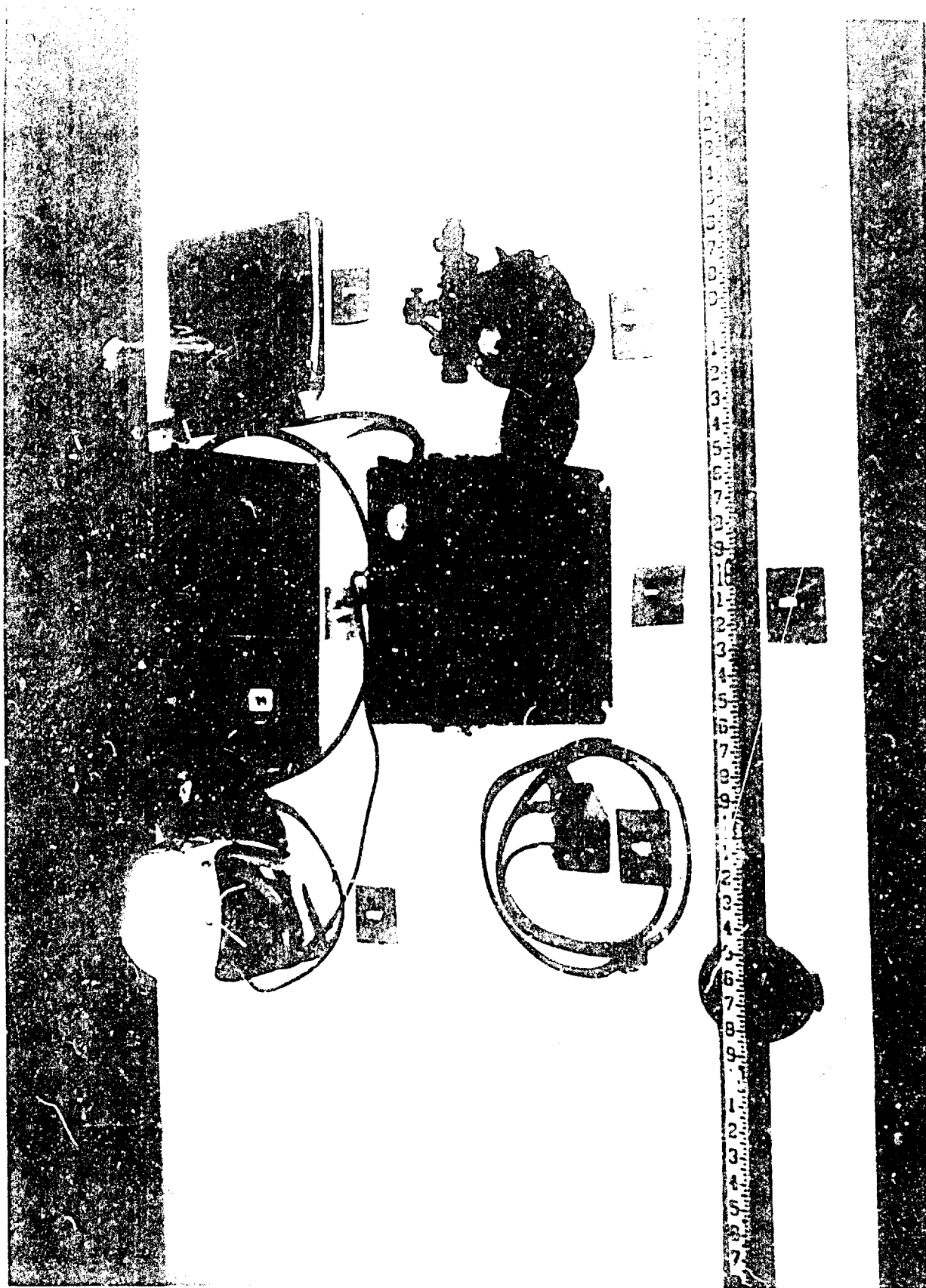
FINAL REPORT

Project 20-1-110

This Photograph shows the Recording and Measurement Equipment Necessary to Conduct this "Ride" Study.

1. General Radio Model 761A Vibration, Displacement and Velocity Meter.
2. Sanborne Strip Chart Recorder (not used during test due to the forces acting on the recording system and absence of suitable mount; therefore, visual readings were recorded directly from the vibration meter).
3. "Lock-on" helmet with Vibration Meter Pickup used in measuring drivers' reaction to ride.
4. Vibration Meter Pickup used in measuring vehicles' reaction to ride.
5. Stadia Rod used in measuring course profile.
6. Transit used in conjunction with Stadia Rod.
7. Notebook of instrument manuals.

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APPENDIX A

HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known exciters.

On pavement the most sensitive tires in terms of "loping" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

TEST PLAN

Establishing the cause of the adverse "ride" reaction of the non-directional radial ply (Group B) tires required a subjective "ride" comparison of the non-directional radial ply tires (Group F) originally used on the "Goer" Tanker. At the conclusion of the tire tread wear and durability study a set of Group F tires formerly applied to the "Goer" Tanker were mounted on one of the Model "C" Tournapull "test beds". Although a direct comparison with the Group B tires was impossible, a complete lap of each test course with the Group F tires indicated little, if any, change in the operator's subjective "ride" experience. This comparative evaluation, however crude, identified Groups B and F as developing similar ride characteristics; consequently, this process of elimination suggested a significant difference in the "ride" reaction of the "Goer" Tanker compared with the Model "C" Tournapull "test beds". To permit a dimensional analysis of the "ride" differences between "Goer" and Model "C" Tournapull, all comparative "ride" reactions were determined by measurements expressed in terms of a "ride" index value.

Each test course was carefully surveyed for particularly significant sections which would support high density test use without change. Upon location of the test course the Group F and the Group A tires at two different inflation pressures were used to establish a constant test speed based on subjective reaction while the vibration meter simultaneously identified the significant exciters and the area of maximum effect. The inflation pressures selected for the "Ride" Study were a compromise based on different pressure build-up rates for the various tires tested as well as different build-up rates for cross-country and pavement-secondary operation. The selection of 50 psig front and 40 psig rear represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 35-40 psig front and 25-30 psig rear. The selection of 40 psig front and 30 psig rear for all three "ride" test courses represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 25-30 psig front and 18-23 psig rear, and for cross-country a cold starting pressure of 30-35 psig front and 20-25 psig rear.

A "Goer" Tanker was available for this comparative "ride" study and was loaded with sufficient liquid ballast to provide a "Goer" GVW equal to its rated GVW with a 5,000 gallon gasoline load (71820#). The Model "C" Tournapull was loaded at a comparable weight and weight distribution.

Two test areas on pavement, one "smooth" and one "rough"; three test areas on secondary, one which was visually "smooth" but generated a significant Model "C" Tournapull "lope", one "smooth" and one "rough"; and one test area in cross-country identified as "rough" represented six significantly different surface conditions, five of which were negotiated at two inflation pressures, while the sixth was the single cross-country area to be negotiated at only one inflation pressure.

CONCLUSIONS

The "Goer" Tanker at rated load provides a significantly better "ride" than the Model "C" Tournapull on rough pavement and secondary road surfaces regardless of tire influence.

In cross-country terrain both vehicles are sharply sensitive to tire differences; specifically, the "Goer" equipped with radial ply non-directional tires is equally as good as the Model "C" Tournapull equipped with directional conventional tires. Inversely when the tire groups are reversed, the "ride" of both vehicles is equally severe.

The natural frequency of both vehicles is sensitive to the type of tires applied. On the Model "C" Tournapull "test bed" the directional conventional tires (Group A) develop 2.15 cycles per second; the non-directional radial ply tires (Group F) develop 1.73-1.80 cycles per second; the non-directional conventional construction tires (Group D) develop 2.00-2.16 cycles per second; and directional radial ply tires (Group E) develop 1.80 cycles per second at 50-40 psig front and 40-30 psig rear. At 30 psig front and 20 psig rear the natural frequency is reduced to 1.50 cycles per second for Groups F and E and 1.80 for Group D.

When the Group A is applied to the "Goer" the natural frequency at 50-40 psig front and 40-30 psig rear is reduced from 1.80 cycles per second to 1.67-1.70 cycles per second. Under the same conditions the Group F natural frequency is reduced from 1.80 cycles per second to 1.70 cycles per second.

Under the eleven test conditions established for the "ride" study the "Goer" vehicle equipped with the directional conventional tires (Group A) exceeded the human fatigue limit (Ride Index 0.89) on three conditions and the vehicle fatigue limit (Ride Index 1.91) on one of these three conditions. The "Goer" vehicle equipped with the non-directional radial ply tires (Group F) exceeded the human and vehicle fatigue limit in cross-country only.

A similar comparison of the influence of tire groups on the Model "C" Tournapull found the Group A tires exceeding the human fatigue limit on five conditions of which two exceeded the vehicle fatigue limit and the Group F tires exceeding the human fatigue limit on six conditions of which three exceeded the vehicle fatigue limit.

The non-directional conventional tires (Group D) and the directional radial ply tires (Group E) were only evaluated on the Model "C" Tournapull. The Group D tires exceeded the human fatigue limit on seven of the eleven conditions of which four exceeded the vehicle fatigue limit. The Group E tires exceeded the human fatigue limit on four of the eleven conditions of which three exceeded the vehicle fatigue limit.

CONCLUSIONS (Contd.)

The subjective "ride" impressions of operators during the tread wear and durability study as well as the operator during the "ride" study confirmed the measured results in terms of "good" and "bad" but without any apparent "feel" for degree of severity once "bad" was reached.

At the beginning of the "ride" study it was necessary to evaluate a subjective "ride" impression expressed by the Model "C" Tournapull operators that one particular type of seat cushion was the most comfortable. By measuring the operator's displacement as influenced by the seat cushion, it was determined that the reduced depth cushion was more comfortable and provided less amplification of input displacement than the deep cushion, consequently the shallow cushion was used throughout the "ride" study.

The non-directional conventional construction tires (Group D) required a speed reduction of 0.6 miles per hour on the rough pavement condition and 1.6 miles per hour on the rough secondary road condition due to the violent reaction of the Model "C" Tournapull at the pre-established test speed.

When driver "ride" measurements are compared with Model "C" Tournapull "ride" measurements under identical conditions, we find the driver generally suffers a proportionately greater increase in amplitude with increased input severity.

Where significant exciters exist, a small increase in vehicle speed (i.e., 1.2 MPH) amplifies Model "C" Tournapull "ride" reaction as much as six times for the Group D tires, four times for the Group F tires and three times for the Group E tires. The Group A tires on the "Goer" indicated no significant increase under the same conditions.

TEST RESULTS

Measured "Ride" Reaction

The results of this study are given on the following pages in tabular and graph form.

Table I summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values. A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

Table II summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Goer" Tanker, in terms of vehicle "Ride" index value. A "ride" index of 1.91 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.8 to 0.9 G). (See GRAPH LEGEND, Figures 1 and 2).

Figure 1 illustrates the "ride" comparison on pavement of each tire group on the Model "C" Tournapull at two inflation pressures.

Figure 2 illustrates the "ride" comparison on pavement of the "Goer" versus the Model "C" Tournapull with Group A and F tires at two inflation pressures.

Figure 3 illustrates the "ride" comparison of each tire group on the Model "C" Tournapull at two inflation pressures under three conditions of secondary road surfaces.

Figure 4 illustrates the "ride" comparison under three conditions of secondary road surfaces of the "Goer" versus the Model "C" Tournapull vehicle with Group A and F tires at two inflation pressures.

Figure 5 illustrates the "ride" comparison of the Model "C" Tournapull versus driver reaction under three conditions of secondary road surfaces on Group F and D tires at two inflation pressures.

Figure 6 illustrates the same conditions as Figure 5 but with Group A and E tires.

Figure 7 illustrates the "ride" comparison of driver on deep versus shallow seat cushion under three conditions of secondary road surfaces using Group D tires on the Model "C" Tournapull at one inflation pressure.

Table 1 (Contd.)

Measures "Ride" Reaction (Contd.)

Figure 8 illustrates the "ride" comparison on cross-country as influenced by the vehicles as well as the tires at one inflation pressure.

Figure 9 illustrates the "ride" comparison of Groups D, E and F under two conditions of pavement at two test speeds on the Model "C" Tournapull and the Group A tires on the "Coar" vehicle at one inflation pressure.

TABLE 1

<u>Condition</u>	<u>Tire Groups</u>							
	<u>A</u>		<u>F</u>		<u>D</u>		<u>E</u>	
Front Tire, pair	40	50	40	50	40	50	40	50
Rear Tire, pair	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>
	<u>"Ride" Index</u>							
<u>Pavement</u>								
#1, Smooth	0.35	0.68	0.51	0.50	0.60	0.30	0.50	0.31
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.60	<u>4.60*</u>	<u>2.00*</u>	<u>2.15*</u>	0.72
<u>Secondary</u>								
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.44	<u>0.98</u>	0.22	0.54
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.24	<u>1.90</u>	0.28	<u>1.40</u>
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	<u>0.91</u>	<u>4.30*</u>	0.75	<u>2.00*</u>
<u>Cross-Country</u>								
Rough	<u>2.7*</u>	--	<u>6.2*</u>	--	<u>10.2*</u>	--	<u>5.8*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

TABLE II

Vehicle Tire Group Condition	Vehicle "Ride" Indices							
	Model "C" Tournapull				"Goer" Tanker			
	A		F		A		F	
Inflation, Front, psig	40	50	40	50	40	50	40	50
Inflation, Rear, psig	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>

Pavement	<u>"Ride" Index</u>							
#1, Smooth	0.35	0.68	0.51	0.50	0.22	0.27	0.31	0.29
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	0.57	0.65	0.80	0.75
Secondary								
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.22	0.56	0.20	0.18
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.20	<u>1.40</u>	0.35	0.38
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	0.51	<u>0.90</u>	0.55	0.62
Cross-Country								
Rough	<u>2.70*</u>	--	<u>6.20*</u>	--	<u>5.70*</u>	--	<u>2.90*</u>	--

	Comparison of Mean Vehicle "Ride" Indices					
	Pavement		Secondary			Cross-Country
	Smooth	Rough	Smooth	Smooth	Rough	Rough
Goer @ 40-30 psig	0.27	0.69	0.21	0.28	0.53	<u>4.30*</u>
"C" Pull @ 40-30 psig	0.43	<u>1.70</u>	0.52	0.45	0.89	<u>4.45*</u>
Goer @ 50-40 psig	0.28	0.78	0.37	0.49	0.75	--
"C" Pull @ 50-40 psig	0.59	<u>0.95</u>	<u>0.93</u>	<u>1.31</u>	<u>2.64*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

GRAPH LEGEND

Figures 1 and 2

Speed: 27.6 Miles Per Hour

<u>Key</u>		<u>Description</u>	
	40 - 50	=	50 PSI Front Tires 40 PSI Rear Tires
	40 - 30	=	40 PSI Front Tires 30 PSI Rear Tires
	Cond. 1	=	Smooth Road
	Cond. 2	=	Rough Road
-----	"Human Limit"	=	Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____	"Vehicle Limit"	=	Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*
	Ride Index	=	Displacement (inches) X frequency (cycles per second)

Note: Speed reduced to 27.0 MPH on D Group, Condition 2, due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure 1

"Add" Comparison On Pavement At Constant Speed And Variable Inflation Pressure

Slide
Number 52

40

40

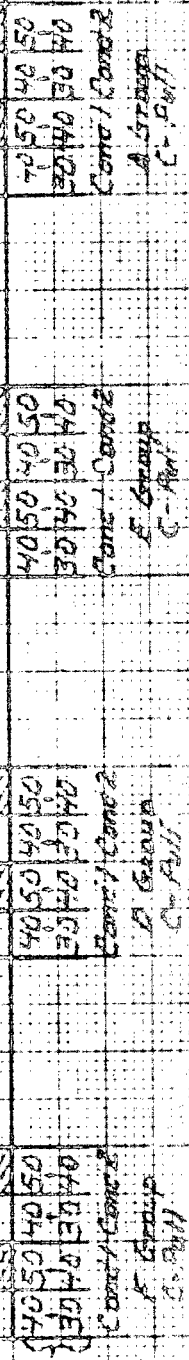
40

Vehicle
Front

40

Vehicle
Rear

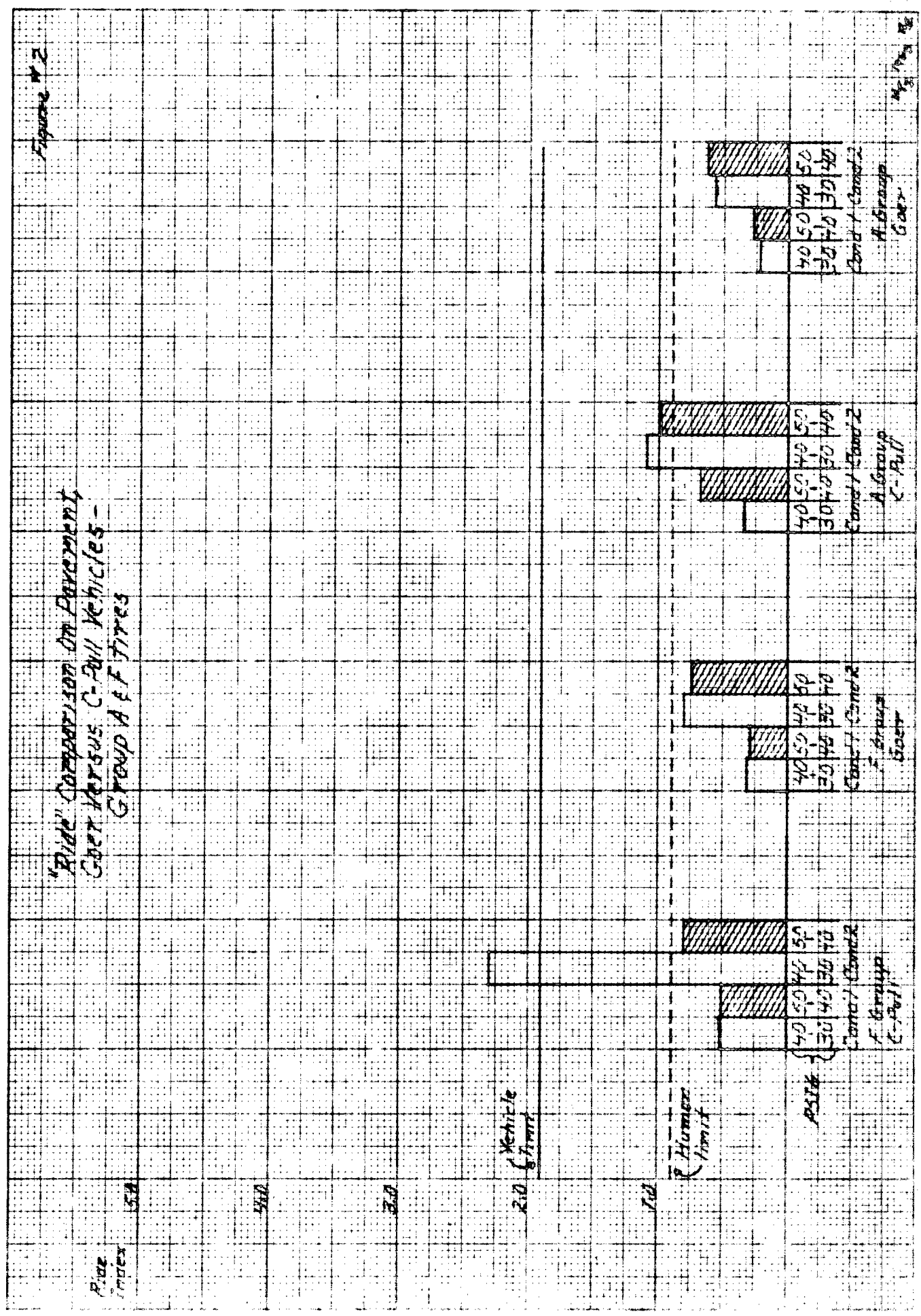
PSI



40 40 40

Figure #2

"Ride" Comparison On Pavement
Coast Versus C-Pull Vehicles -
Group A & F Tires



GRAPH LEGEND

Figures 3 and 4

Speed: 22.6 Miles Per Hour

Key	Description
	= 50 PSI Front Tires 40 PSI Rear Tires
	= 40 PSI Front Tires 30 PSI Rear Tires
Cond. 1	= 100 Foot Smooth Road Section Acting as Lope Generator
Cond. 2	= 100 Foot Smooth Road Section
Cond. 3	= 100 Foot Road Section with Three Exciters Followed by a Smooth Road Section
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____ "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure #3

"Ride" Comparison on Secondary Roads at Constant Speed and Variable Inflation Pressure

Ride Index

5.0

4.0

3.0

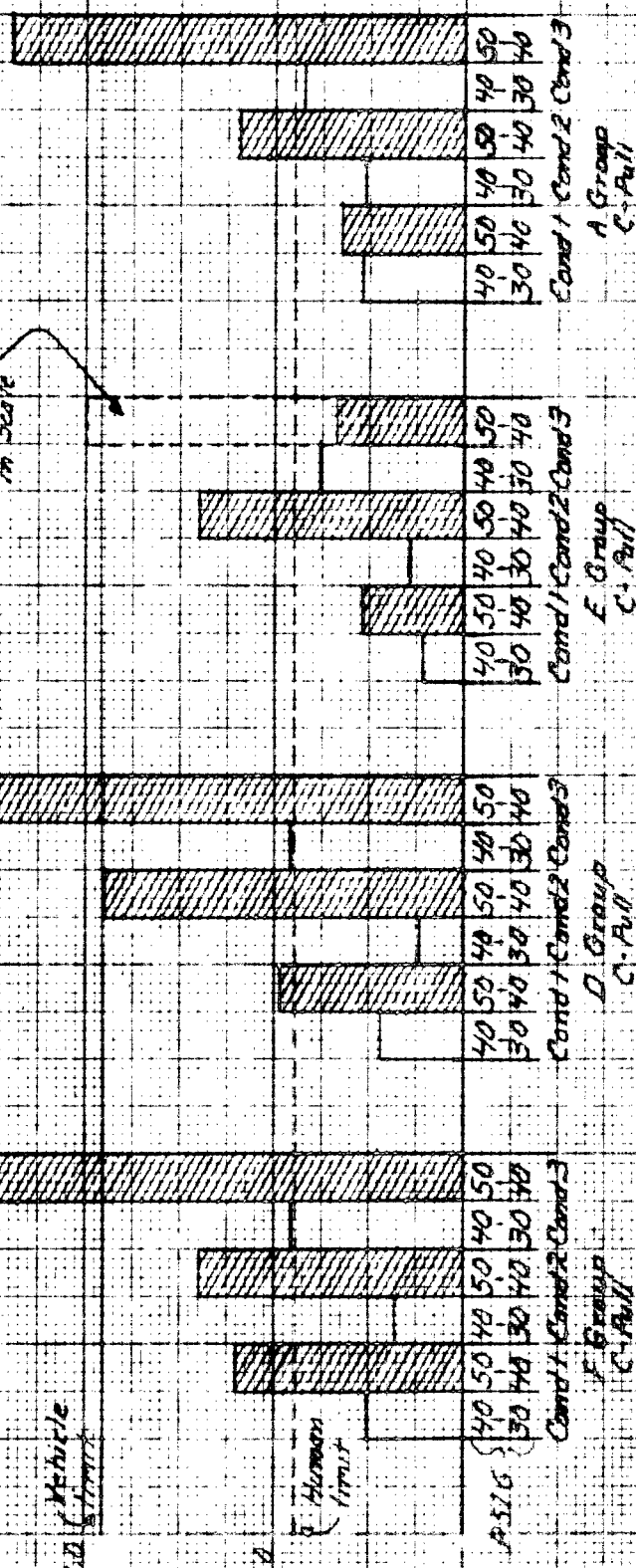
2.0

1.0

Vehicle Stimulus

Human Limit

Note: 1.67 Converted to 2.0 Due to Change in Scale



A Group
C-Pull

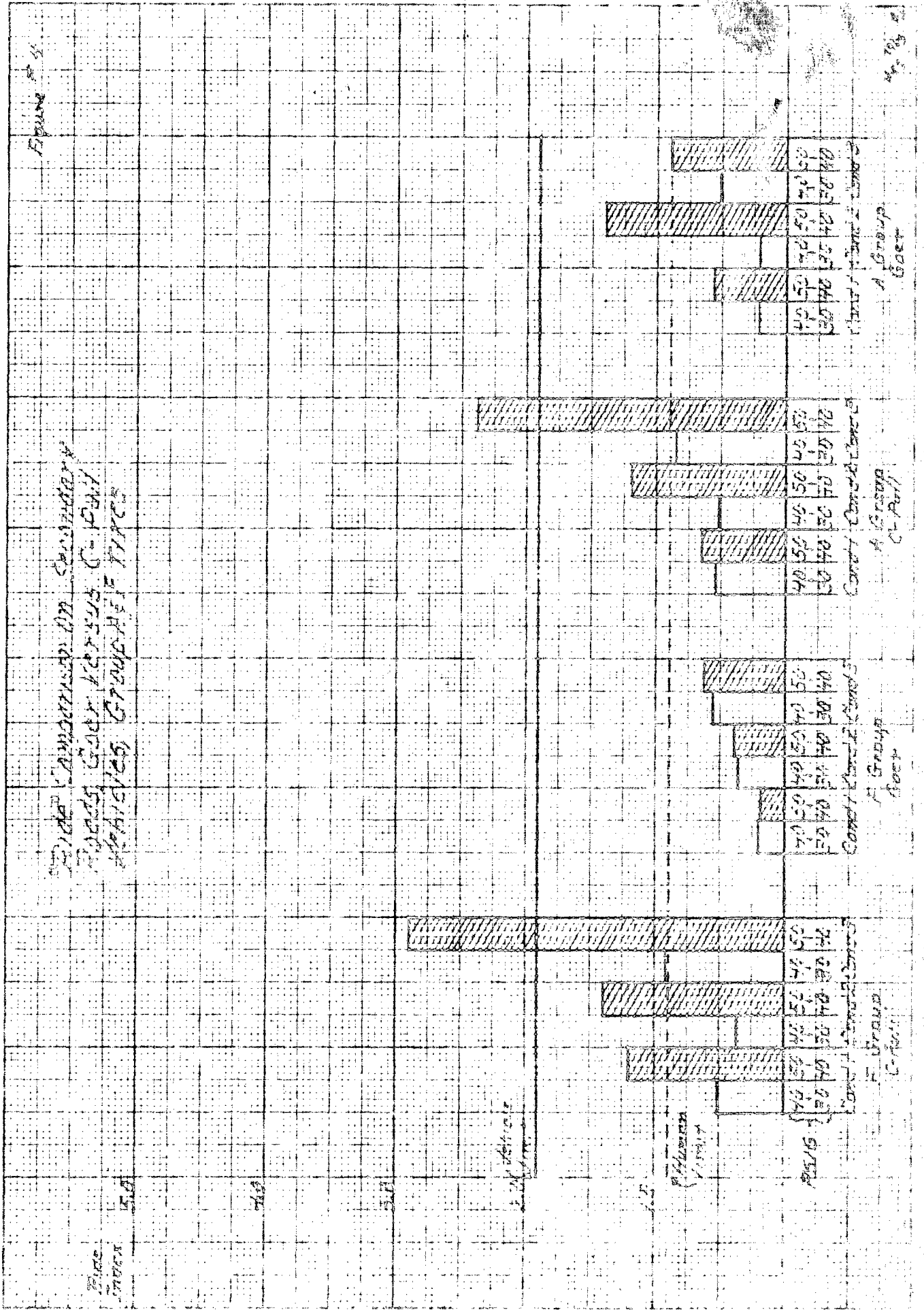
E Group
C-Pull

D Group
C-Pull

F Group
C-Pull

Figure 4

Side View of the
 1000 Series
 1000 Series
 1000 Series



GRAPH L E G E N D

Figures 5 and 6

Speed: 22.6 Miles Per Hour

Key	Description
 V	= Vehicle Reaction-40 PSI Front Tires 30 PSI Rear Tires
 D	= Driver Reaction-40 PSI Front Tires 30 PSI Rear Tires
 V	= Vehicle Reaction-50 PSI Front Tires 40 PSI Rear Tires
 D	= Driver Reaction-50 PSI Front Tires 40 PSI Rear Tires
Cond. 1	= 100 Foot Smooth Road Section Acting as Lope Generator
Cond. 2	= 100 Foot Smooth Road Section
Cond. 3	= 100 Foot Road Section with Three Shallow Exciters Followed by a Smooth Road Section
---- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____ "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure 8

Comparison of Secondary Road
of Vehicle & Driver on 3" Seat Cushion
at Constant Speed with Two
Pressures

PSI

40

40

40

Vehicle
Pressure

Pressure
Group 3

PSI

40

50

60

70

80

90

100

110

120

130

140

150

160

170

180

190

200

210

220

230

240

250

260

270

280

290

300

310

320

330

340

350

360

370

380

390

400

410

420

430

440

Cond 1

Cond 2

Cond 3

Group
C-1

Group
C-2

Group
C-3

Group
C-4

Group
C-5

Group
C-6

Group
C-7

Group
C-8

"Rude" Comparison on Secondary Road
 of Vehicle & Driver on 3rd Class
 at Consistent Speed with Two Tires

7 cc
 7000x SE

2.0

3.0

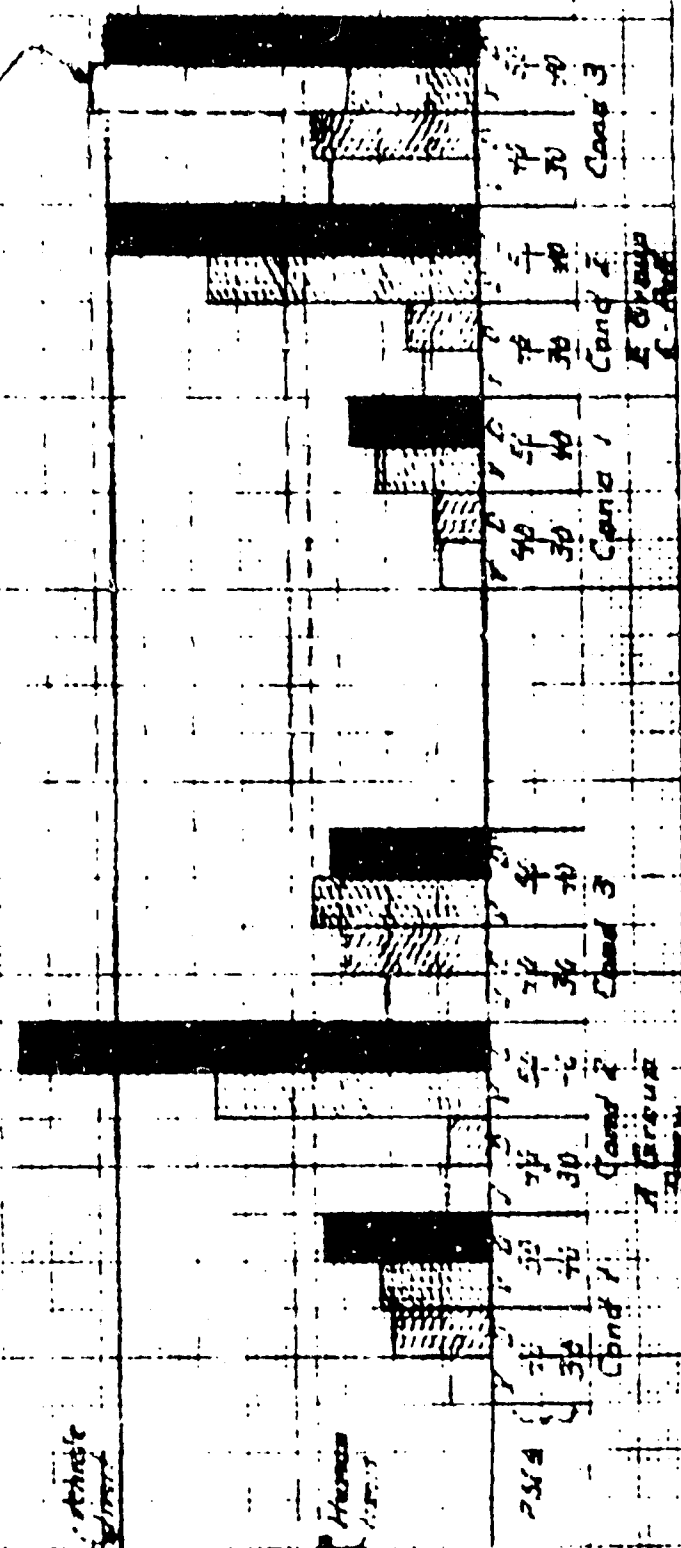
2.0
 Athlete
 1.5

1.0

1.0
 1.5

2500

2.0 Due to Change
 in Speed



GRAPH L E G E N D

Figure 7

Speed: 22.6 Miles Per Hour

40 PSI Front, 30 PSI Rear

Key		Description	
	Cond. 1	=	100 Foot Smooth Road Section Acting as Lope Generator
	Cond. 2	=	100 Foot Smooth Road Section
	Cond. 3	=	100 Foot Road Section with Three Shallow Exciters Followed by a Smooth Road Section
-----	"Human Limit"	=	Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____	"Vehicle Limit"	=	Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

- * Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

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Figure 1

Under Compression on Secondary End of
Driver on S.F. 3. Not Custom at A
Constant Speed and Rotation Pressure

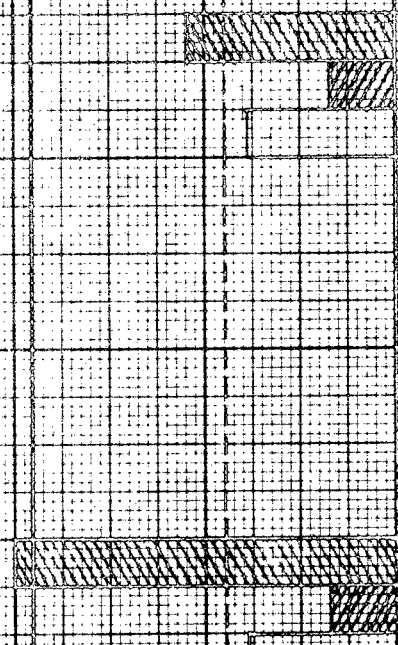
Under
Driver 50

50

50

50
6-Stroke
Cylinder

60
2-Stroke
Cylinder



50-50
Cond 1 2 3
2-Stroke Cylinder

50-50
Cond 1 2 3
2-Stroke Cylinder

GRAPH L E G E N D

Figure 8

Speed: 7.4 Miles Per Hour

40 PSI Front, 30 PSI Rear

Course Involved 3 Depressions and 3 Lifts

Key	Description
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____ "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure 10 B

Side Comparison for Time & Vehicle on
Cross Country at Constant Speed
With and Without Pressure

Side
Index

100

90

80

70

60

50

40

30

Vehicle
Limit

Human
Limit



D Group
C-PUH
40-50

E Group
C-PUH
40-50

F Group
C-PUH
40-50

G Group
GOW
40-50

A Group
C-PUH
40-50

A Group
GOW
40-50

45 40 35

GRAPH L E G E N D

Figure 9

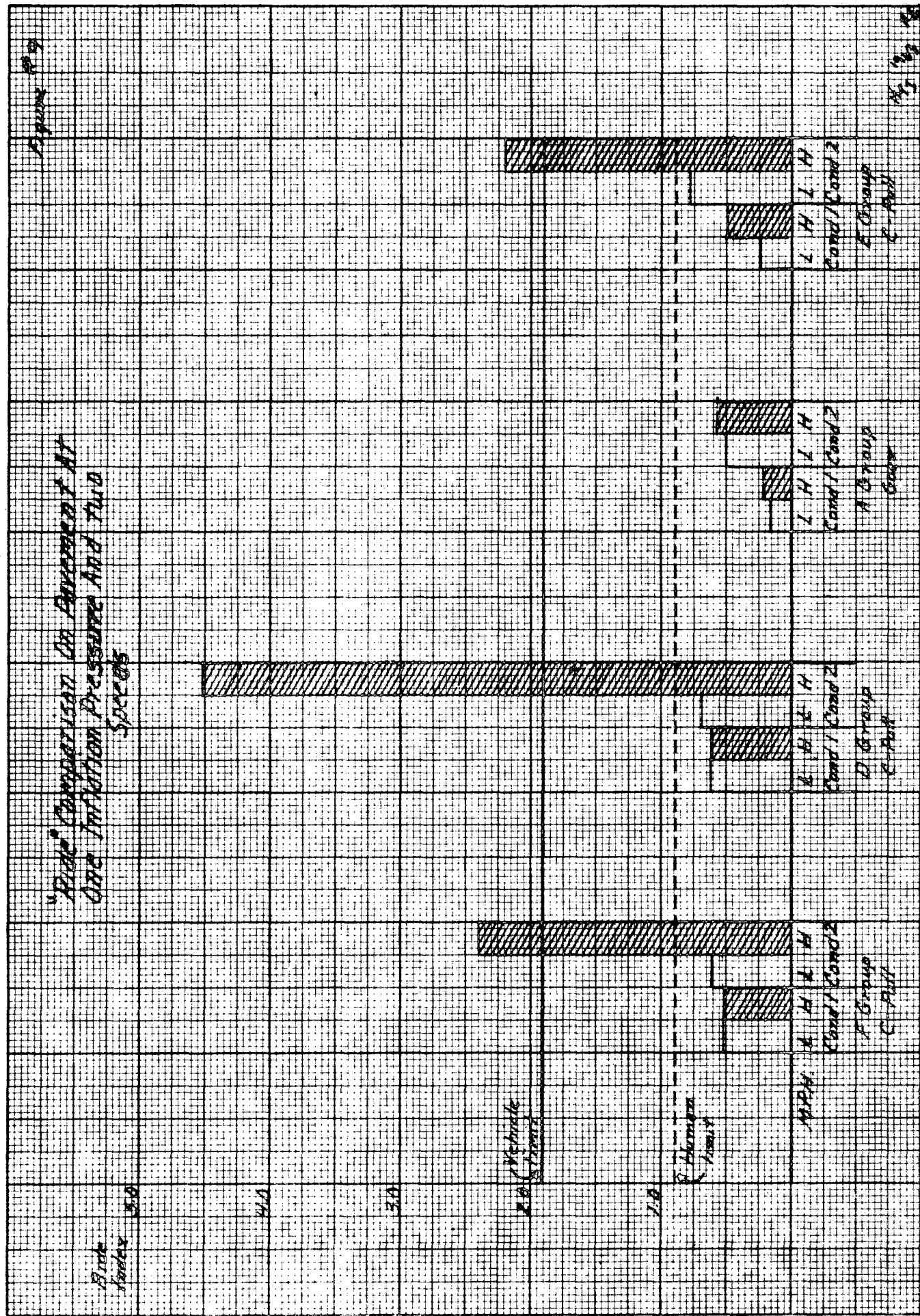
40 PSI Front, 30 PSI Rear

Key	Description
 L	= 26.4 Miles Per Hour
 H	= 27.6 Miles Per Hour
Cond. 1	= Smooth Road
Cond. 2	= Rough Road
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
_____ "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Figure #9

"Ride" Comparison On Pavement At
One Inflation Pressure And Two
Speeds



TEST RESULTS (Contd.)

Subjective "Ride" Reaction

The following table reflects the operator's "ride" impressions of the two tire Groups D and E which were added to the tread wear and durability test and the tire Group F which was of similar construction and design as the Group B tires.

Preference Driver #	Pavement							Secondary							Cross-Country						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
1st	DE	DE	-	DE	DE	-	-	E	E	DE	E	DE	E	-	FE	-	FE	FE	-	FE	FE
2nd	F	F	-	F	F	-	-	DF	DF	F	DF	F	DF	-	D	-	-	D	D	D	D

TEST PROGRAM

Test Courses

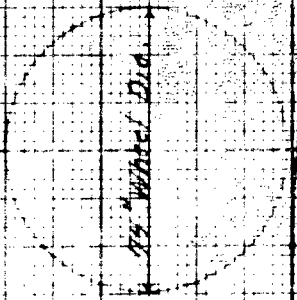
Pavement - A portion of Nevada Automotive Test Center's highway pavement test course #2 (abandoned U.S. Highway 50) was chosen to provide two test sections. Test section #1 was smooth, whereas test section #2 (See Road Profile of Pavement Test Section Figures #1 and #2) was of rolling contour featuring two major excitors.

Secondary - A portion of Nevada Automotive Test Center's secondary test course having a compaction of 300+ PSI was chosen to provide three test sections. Test section #1 was a visually smooth surface which generated "lope" in the Model "C" Tournapull units. Test section #2 was smooth surface creating no lope. Test section #3 (See Road Profile of Secondary Test Section #3 Figures #3 and #4) was of rolling contour featuring three major excitors.

Cross-Country - A section of Nevada Automotive Test Center's cross-country test course was chosen as a severe but not extreme condition. This test section provided three excitors (See Road Profile of Cross-Country Test Section Figure #5).

Figure #1

Plan Profile of Pavement Test Section #2
Indicating Major Exciters
12 ft 40 ft



As Wheel Did

Grade Line

133' Elev

16'

133'

2.3' Depth

Scale
Vert 1" = 1.5'
Hori 1" = 4'

Post Section #2 Cont
Elevation #2

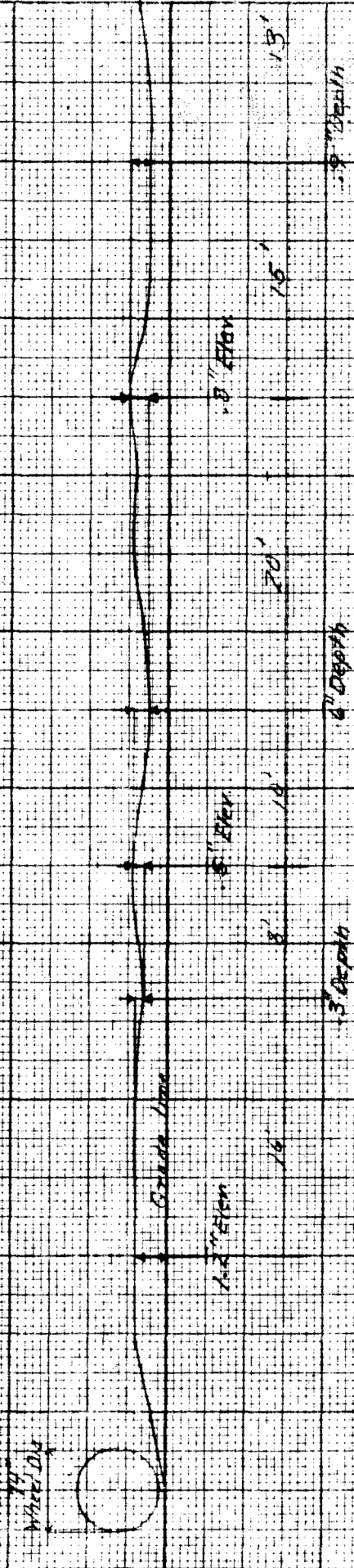
Point of Intersection Post Section #2
Indicating No. of Feet
From 40 ft

1.98" Depth

Scale
Vert 1" = 1.5'
HORIZ 1" = 4'

Figure #3

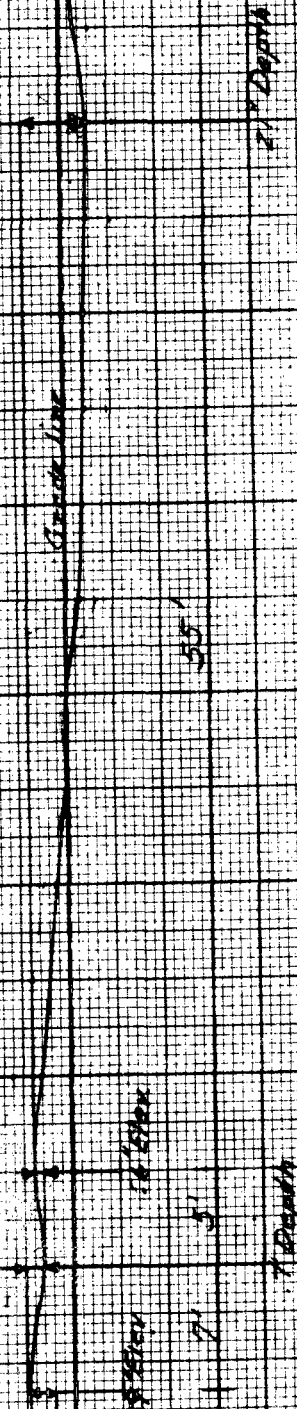
Good Profile of Secondary Test Section #3 Indicating Major Exciters First 100 ft



Scale
Vert 1" = 6'
Hori 1" = 10'

East Section 13 Cont.
Figure 14

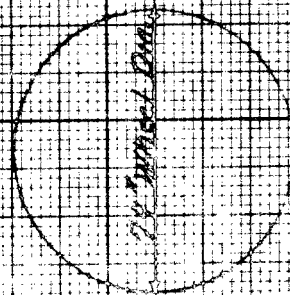
East Profile of Secondary East Section 13
Indicating Major Features
Second 100 FT



SCALE
VERT. 1" = 10'
HORIZ. 1" = 10'

Figure 10.5

ROAD PROFILE OF CROSS COUNTRY TEST SECTION INDICATING MAJOR EXCISES



Grade Line

20' Elev

25' Elev

31' Elev

21' Elev

11'

2.6'

5'

4.0' Depth

3.0' Depth

1.2' Depth

SCALE

VERT. 1" = 8'

HORIZ. 1" = 4'

TEST PROGRAM (Contd.)

Test Vehicles

One Model "C" Tournapull

One "Goer" Tanker XM438E2

Test Tires

Two of the five groups which ran on the tread wear and durability evaluation (Groups D and E) were subjected to the "ride" study. The Groups A, B and C tires were not available but a Group A and a Group F were substituted and were of similar design and construction as the Group A and Group B tires. Thus the following test groups were subjected to the "ride" evaluation:

Group A, Conventional construction directional tread.

Group D, Conventional construction non-directional tread.

Group E, Radial ply construction directional tread.

Group F, Radial ply construction non-directional tread.

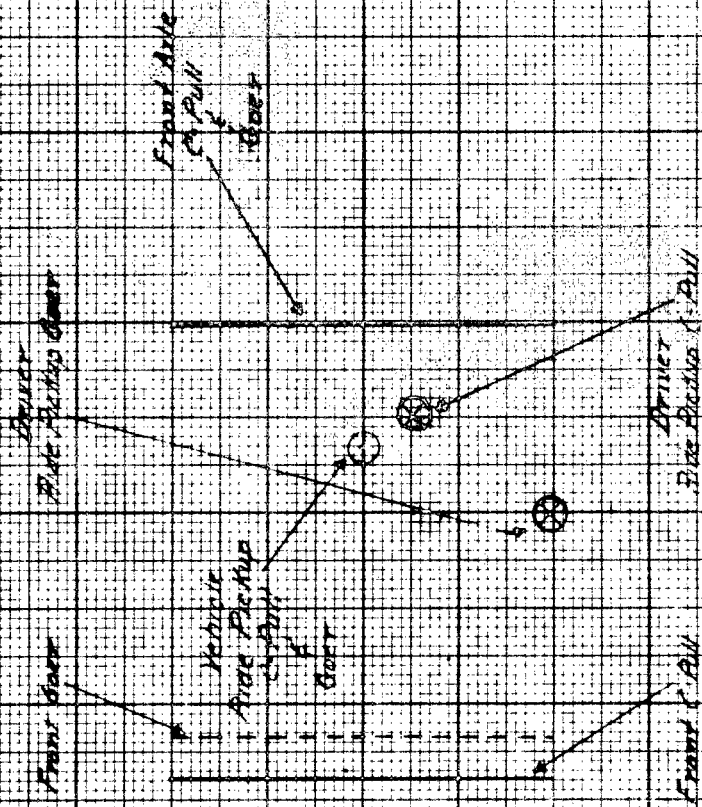
Test Procedure

To evaluate comparative vehicle "ride" a vibration pickup location common to both Model "C" Tournapull and the "Goer" Tanker vehicle was chosen (approximately on centerline and 2 feet 7 inches ahead of the front axle). An average of two runs plus reruns as required were made at each inflation pressure, under each test condition, for the three test courses, on each group of test tires.

To evaluate driver reaction to vehicle "ride" a lock-on helmet was instrumented with a vibration meter pickup.

The following schematic shows the location of the Vibration Meter Pickups relative to the front axle position of both the Model "C" Tournapull and the "Goer" Tanker vehicle.

Field Survey
 Placement of Instrument Meter Pickup
 In Relation to Front Side Center Line
 Comparing C-Pull & Goer Vehicles



Rear Side Goer

Rear Side C-Pull

Scale
 $\frac{1}{4}'' = 1'$

APPENDIX B

FINAL REPORT

Project 20-1-110

Shallow Mud Traction of
Tire Groups A and B Type

July 1963

Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada

APPENDIX

FINAL REPORT

Project 20-1-110

Upper Photograph

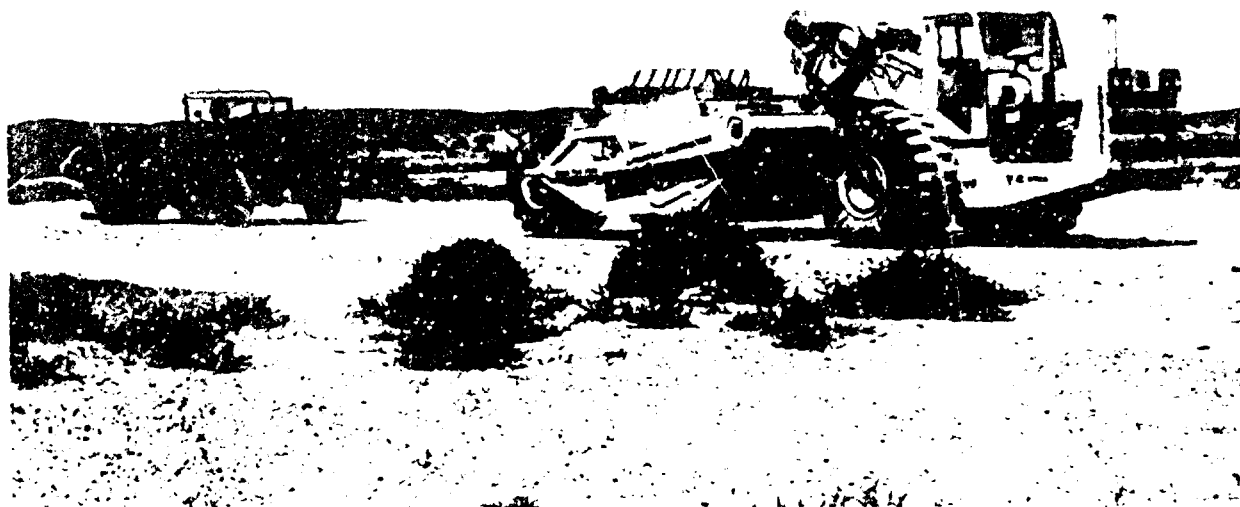
Mud Test Area

Lower Photograph

Mud Test Equipment Conveyor

NOT REPRODUCIBLE

Best Available Copy



APPENDIX A

HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known exciters.

On pavement the most sensitive tires in terms of "lope" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

TEST RESULTS

Figure 1 indicates the maximum traction developed by the two groups tested at each inflation pressure under investigation. Also shown on this graph at two inflation pressures is a profile of tire penetration in the test track. From these profiles the portion of the tread surface providing the most aggressive traction is apparent.

Figure 2 illustrates the complete Group A traction curve for each inflation pressure tested.

Figure 3 illustrates the complete Group F traction curve for each inflation pressure tested.

TEST PROGRAM

Test Course

A test course area was selected to provide high natural compaction affording minimal tire penetration and low coefficient of friction (.17-.25) when wet. The character of this course may be compared with wet grass matted slopes.

Separate test courses were constructed and used each day of test operation. Each test course was approximately 65 feet in length and 20 feet in width.

Test Vehicle and Dynamometer Unit

A Model "C" Tournapull was used as the "test bed" unit and an M-34 2 1/2 ton 6x6 vehicle, fully instrumented for this study, was used as the dynamometer unit.

Test Procedure

With the "test bed" vehicle attached to the Emery Load Cell System installed in the dynamometer unit the two vehicles, "test bed" vehicle leading, moved down the test course approach apron and stabilized at test speed with essentially zero pounds tractive force before entering the mud pit. After the "test bed" vehicle had entered the mud pit, the dynamometer vehicle slowly applied a resisting force inducing "test bed" wheel slip until zero forward motion or vehicle stall condition was achieved although the wheel speed of the "test bed" vehicle was maintained constant. Ground speed was recorded by means of a fifth wheel instrumented with a Weston DC tachometer generator. Two signals being produced simultaneously (pounds drawbar force and ground speed) were integrated and plotted by means of HTI function plotting recorder. This provided a recording of the complete traction curve for each run. An average of six runs was made at each inflation pressure for each group tested.

DYNAMIC TRACTION STUDY IN SHALLOW MUD

PROJECT 20-1-110

MAXIMUM TRACTION GROUPS A&F

FIGURE 1

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

GROUND LEVEL

PROFILE OF TIRE PENETRATION

GROUND LEVEL

LEGEND

* GROUP A - FIRESTONE SUPER GRIND GRIP 60ER W.D. DIRECTIONAL (CONTROL)

x GROUP F - U.S. TACTICAL M.S. RADIAL PLY CONSTRUCTION NON-DIRECTIONAL

INFLATION, PSIG

MAXIMUM POUNDS DRAWBAR

10000

9000

8000

7000

6000

5000

55

50

45

40

35

30

25

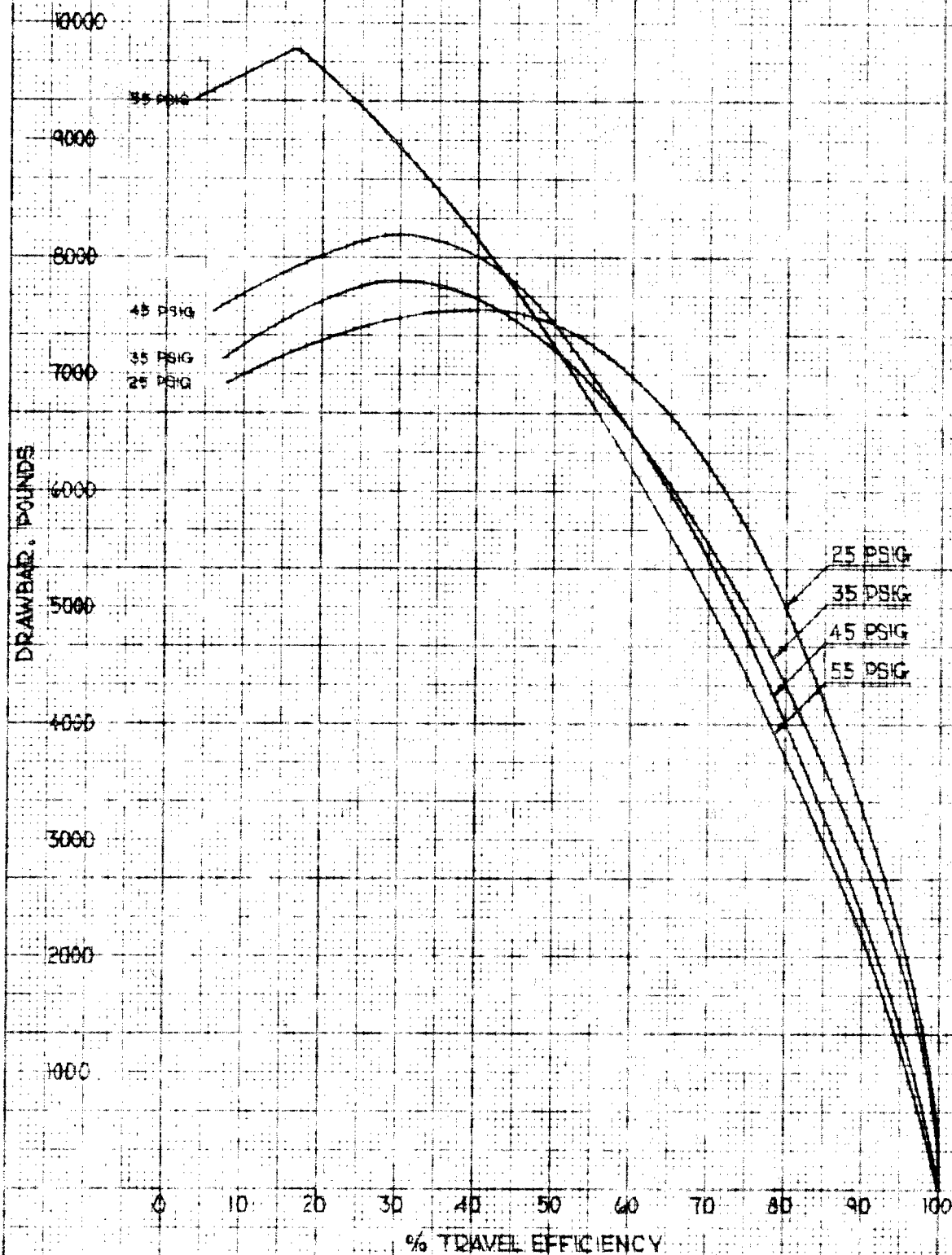
20

15

45

DYNAMIC TRACTION IN SHALLOW MUD
GROUP "A" TIRES
PROJECT 20-1110

FIGURE 2

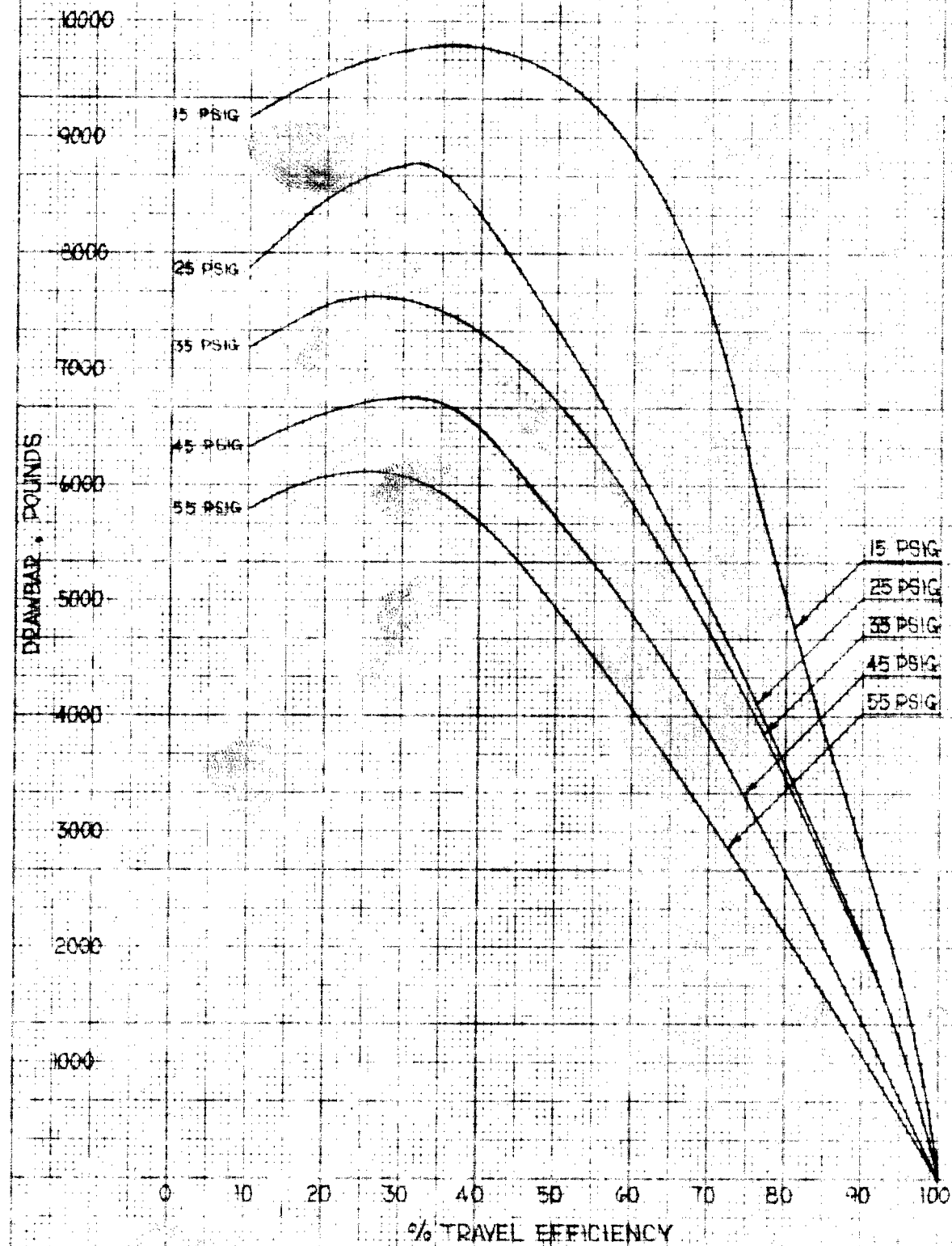


SCALE: 1 INCH = 1000 LBS

DYNAMIC TRACTION IN SHALLOW MUD

FIGURE 3

GROUP F TIRES
PROJECT 20-110



SCALE: 1 SQ. = 66.7 LBS.

M. B. W.

DEEP MUD TEST

Discussion

A specially constructed pit was required in which the depth of mud was 12 inches, the length of the pit was 220 feet and the width 40 feet. The consistency of the mud was maintained to a state wherein the vehicle would become immobile before the 220 feet distance was reached. The evaluation of one tire versus the other was made on the basis of distance traveled versus time. The vehicle remained in the same transmission gear throughout all tests, and when it became immobile the tires would spin out and not stall out. The test bed vehicle was such that only the front drive axle could be used; therefore, throughout all tests the rear axle was non-driving and the same set of tires remained on the rear axle throughout all tests. Experiments were conducted in respect to what effect inflation would have, and since there was no effect, all tests were conducted at a standard setting of 40 psi per tire. The depth of mud was determined to be the maximum allowable depth without high centering the vehicle. Inasmuch as no torque was transmitted to the rear axle, it was observed throughout each test that these tires would slide and in turn build up a large quantity of mud directly in front of each wheel. By the resistance created at this point, it increased the drag on the vehicle and in turn the front driving tires were called upon to do more work than would be expected if both axles were driving. Therefore, these tests are only a comparative type test of the three experimental groups as compared with the control group. By reviewing the attached data it will be noticed that the control tires, along with the experimental tires, have operated through the pit a total of three runs each, alternating from the control to the experimental, etc. After each run, the pit was floated down with a leveling device.

Due to a test bed vehicle breakdown, we were unable to compare the Ground Grip Directional Grooved Lugs.

TEST RESULTS:

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

<u>Time</u>	<u>Distance</u>	<u>Rating</u>
1. 41 Sec.	98' 10"	
3. 42 Sec.	101' 3"	
5. <u>43 Sec.</u>	<u>94' 10"</u>	
Total..126 Sec.	294' 11"	
Average..42 Sec.	98' 3"	100

SUPER GROUND GRIP GOER

<u>Time</u>	<u>Distance</u>	<u>Rating</u>
2. 91 Sec.	177' 10"	
4. 82 Sec.	165' 9"	
6. <u>79 Sec.</u>	<u>161' 1"</u>	
Total..252 Sec.	504' 8"	
Average.. 74 Sec.	168' 2"	171

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

<u>Time</u>	<u>Distance</u>	<u>Rating</u>
1. 54.5 Sec.	86' 9"	
3. 58 Sec.	86' 1"	
5. <u>54.5 Sec.</u>	<u>85' 1"</u>	
Total..167 Sec.	257' 11"	
Average..55.6 Sec.	85' 11"	100

ND-CC GOER

<u>Time</u>	<u>Distance</u>	<u>Rating</u>
2. 26 Sec.	48' 3"	
4. 24 Sec.	47' 3"	
6. <u>26 Sec.</u>	<u>48' 7"</u>	
Total...76 Sec.	144' 1"	
Average...25.3 Sec.	48'	56

APPENDIX

I. Abbreviations and Symbols	p i
II. Glossary of Trade Names	p ii
III. Deflection Sheets	p iii

APPENDIX I

ABBREVIATIONS AND SYMBOLS

°C	Degrees Centigrade
°F	Degrees Fahrenheit
FR-S	Firestone Rubber - Synthetic (styrene-butadiene type)
in	Inches
lb	Pounds
NR	Natural Rubber
psi	Pounds per square inch

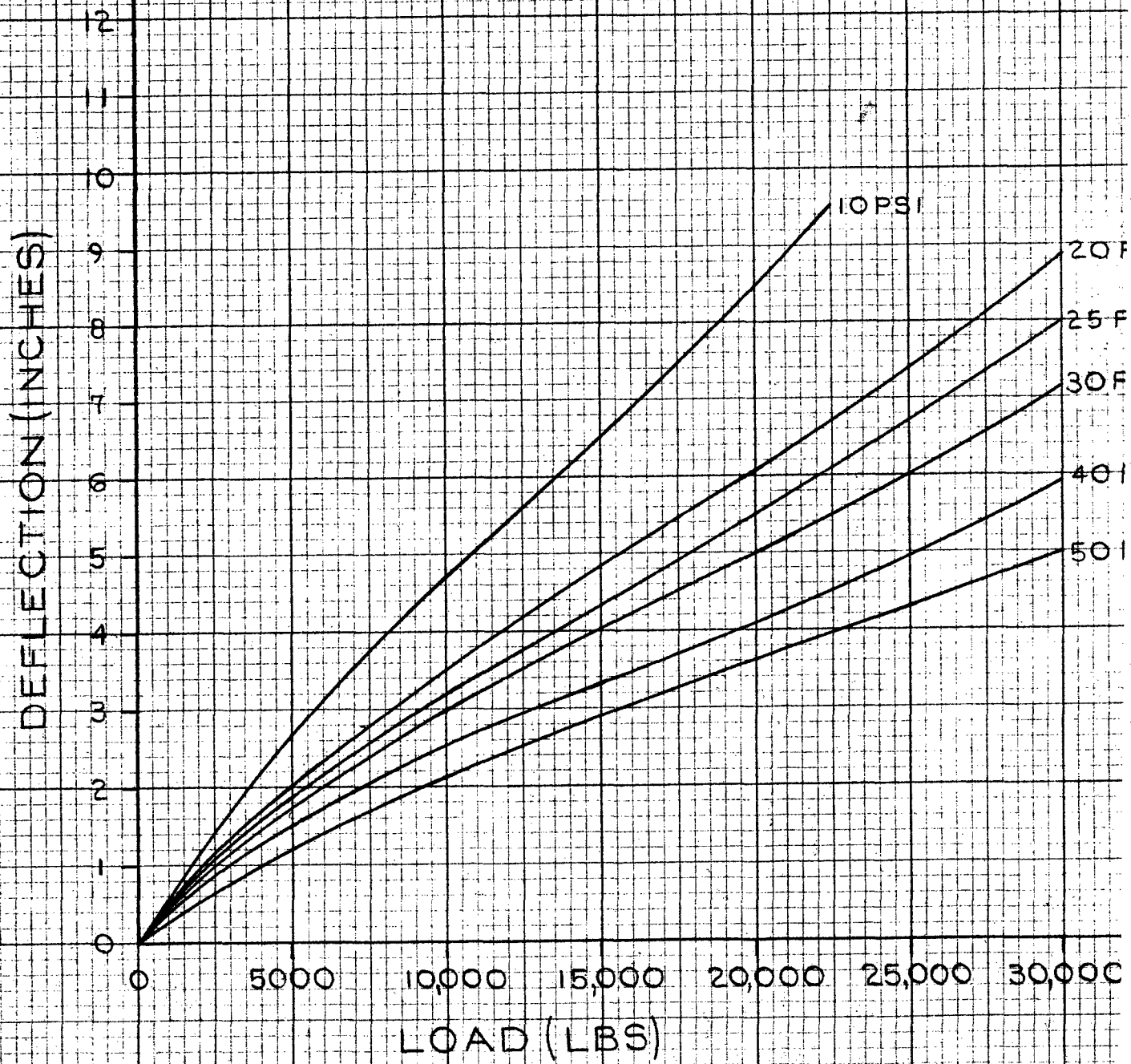
APPENDIX II

GLOSSARY OF TRADE NAMES

<u>TRADEMARK OR DESIGNATION</u>	<u>COMPOSITION</u>	<u>USE</u>	<u>SOURCE</u>
Isoprene	polyisoprene	Elastomer	Shell Chemical
Diene	polybutadiene	Elastomer	Firestone Tire & Rubber Co.
FR-S 123	butadiene-styrene copolymer oil masterbatch-31 phR oil	Elastomer	Firestone Tire & Rubber Co.
Hypalon	chlorosulfonated polyethylene	Elastomer	duPont
Neoprene	polychloroprene	Elastomer	duPont

①

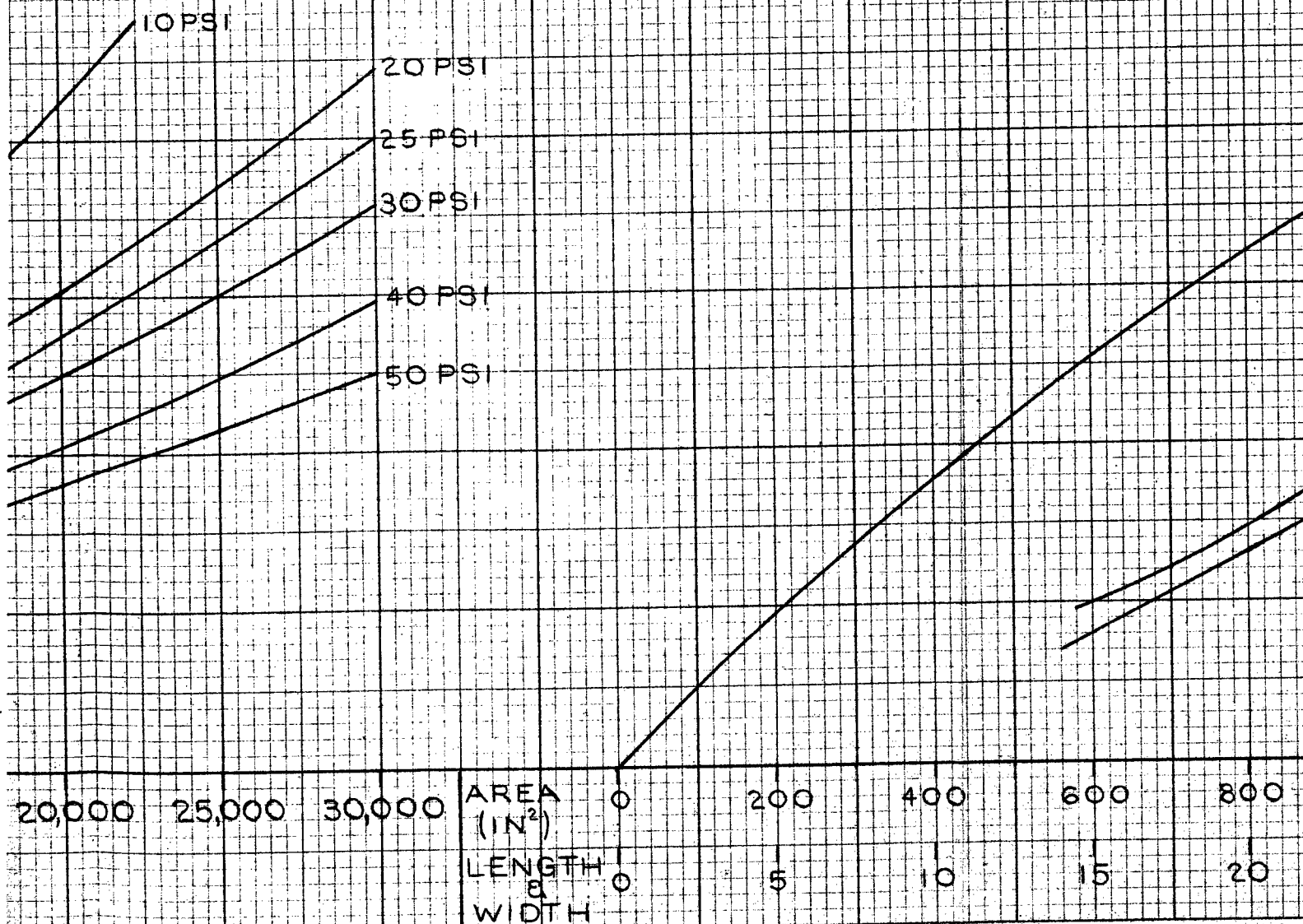
29.5-25 SUPER GROUND LOAD-DEFLECTION~(



②

SUPER GROUND GRIP GOER (16)

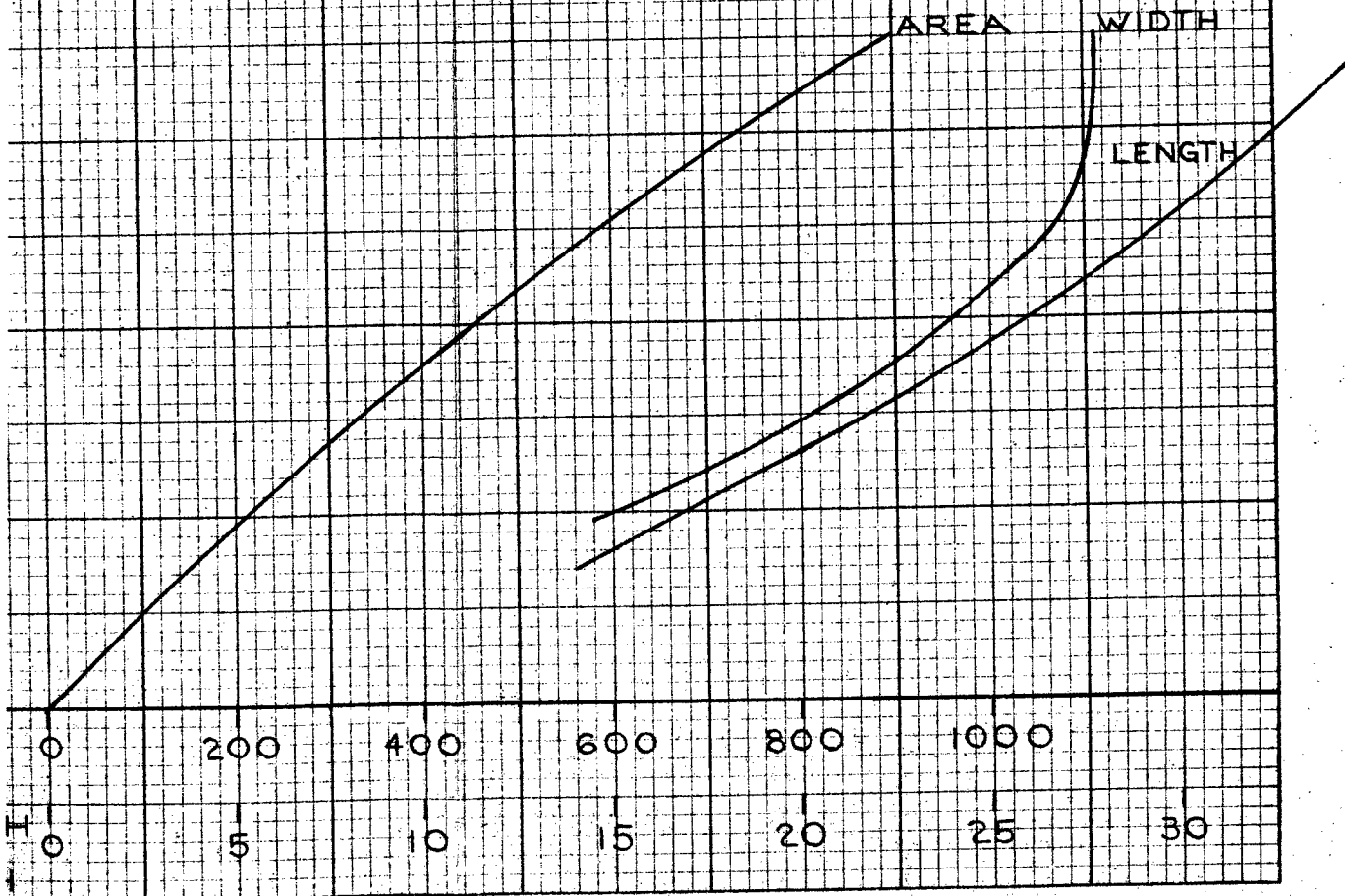
~DEFLECTION~CONTACT AREA



③

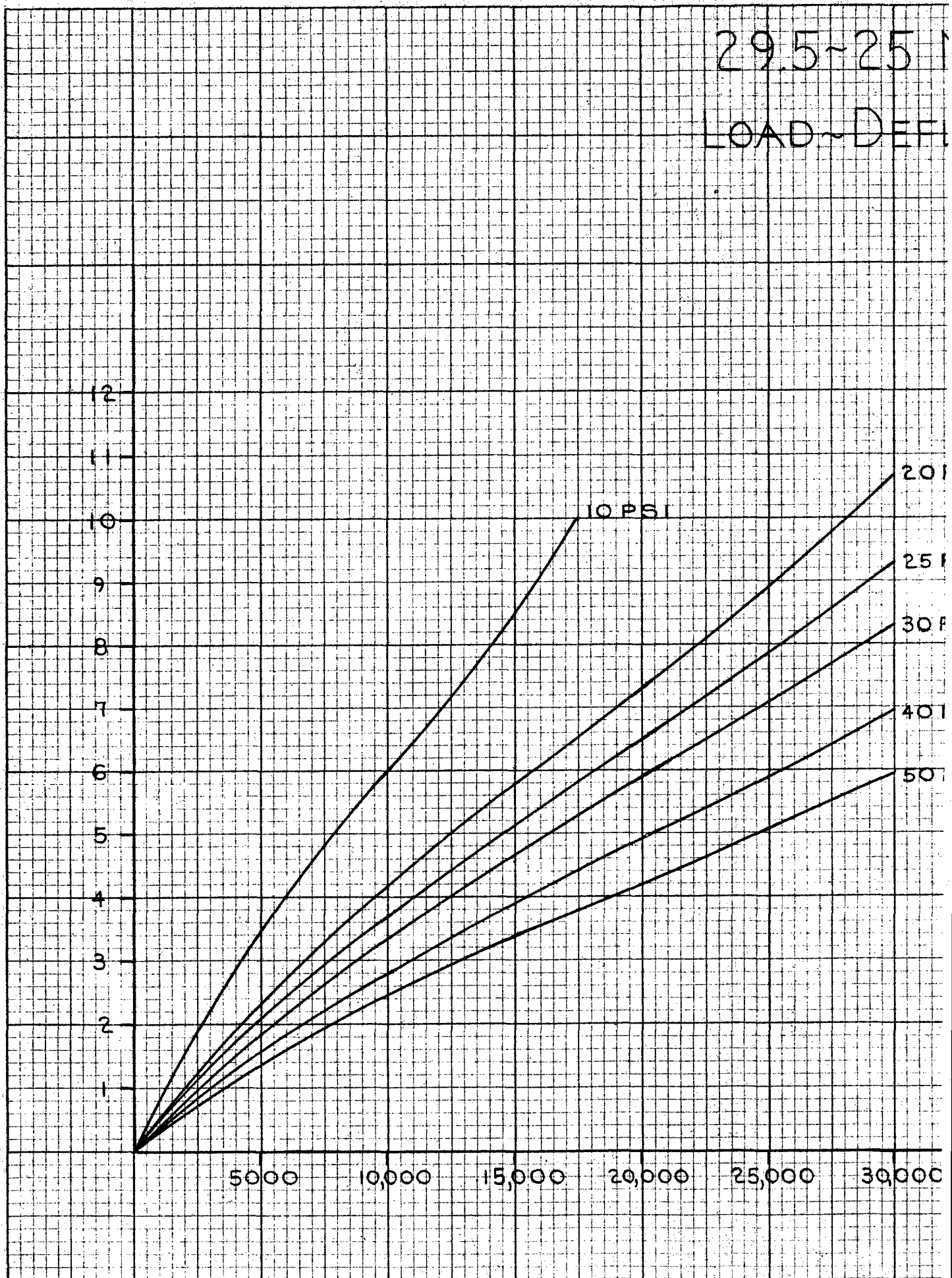
JP GOER (16)

ACT AREA



①

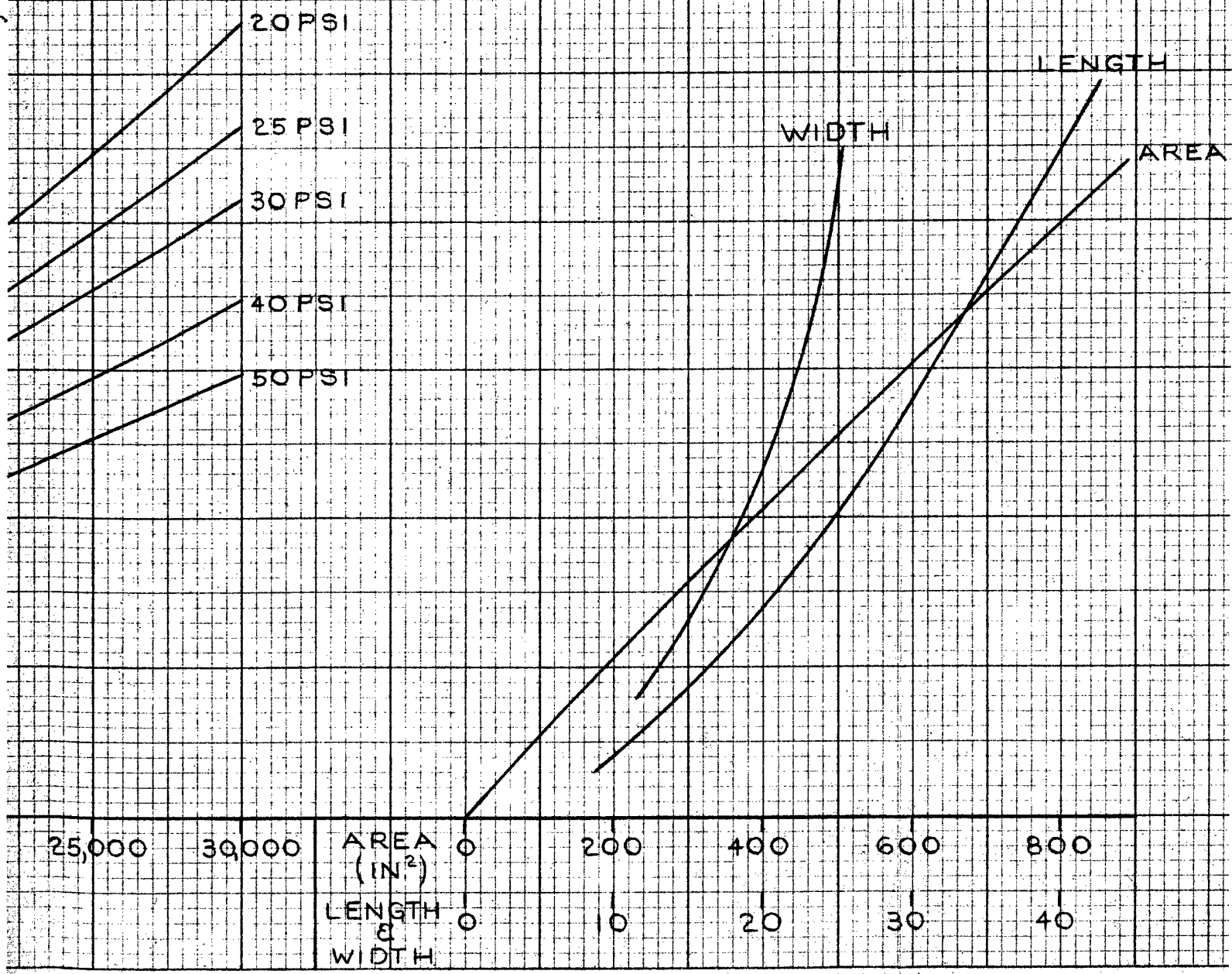
29.5~25
LOAD~DEF



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29.5-25 ND-CC GOER(16)

LOAD~DEFLECTION~CONTACT AREA



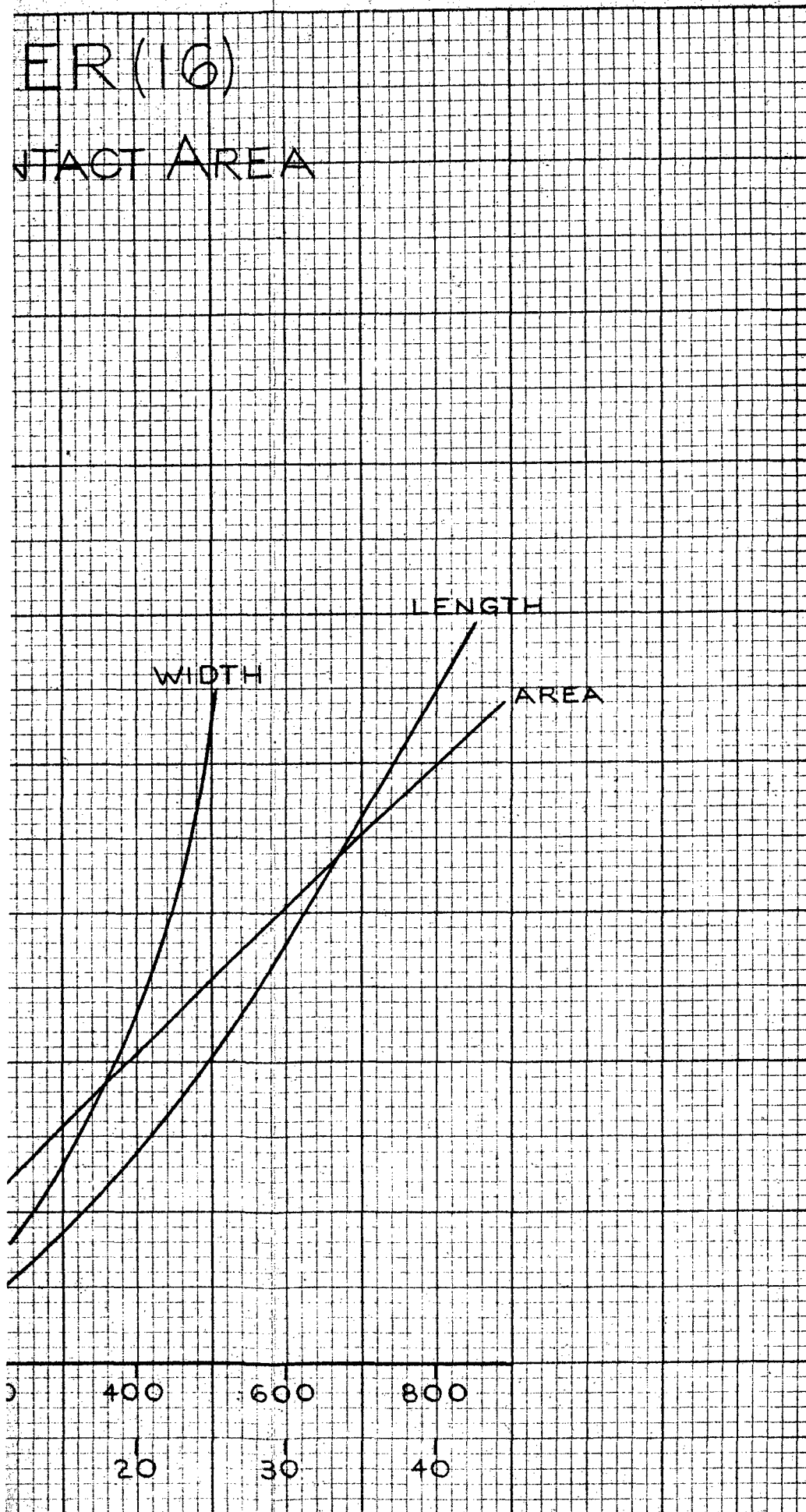
ER(16)

CONTACT AREA

WIDTH

LENGTH

AREA



①

29.5-25 S

LOAD-[

K&E 10 X 10 TO THE INCH 35f 7LG
KEUFFEL & ESSER CO. MA U.S.A.

DEFLECTION (INCHES)

12
11
10
9
8
7
6
5
4
3
2
1
0

0

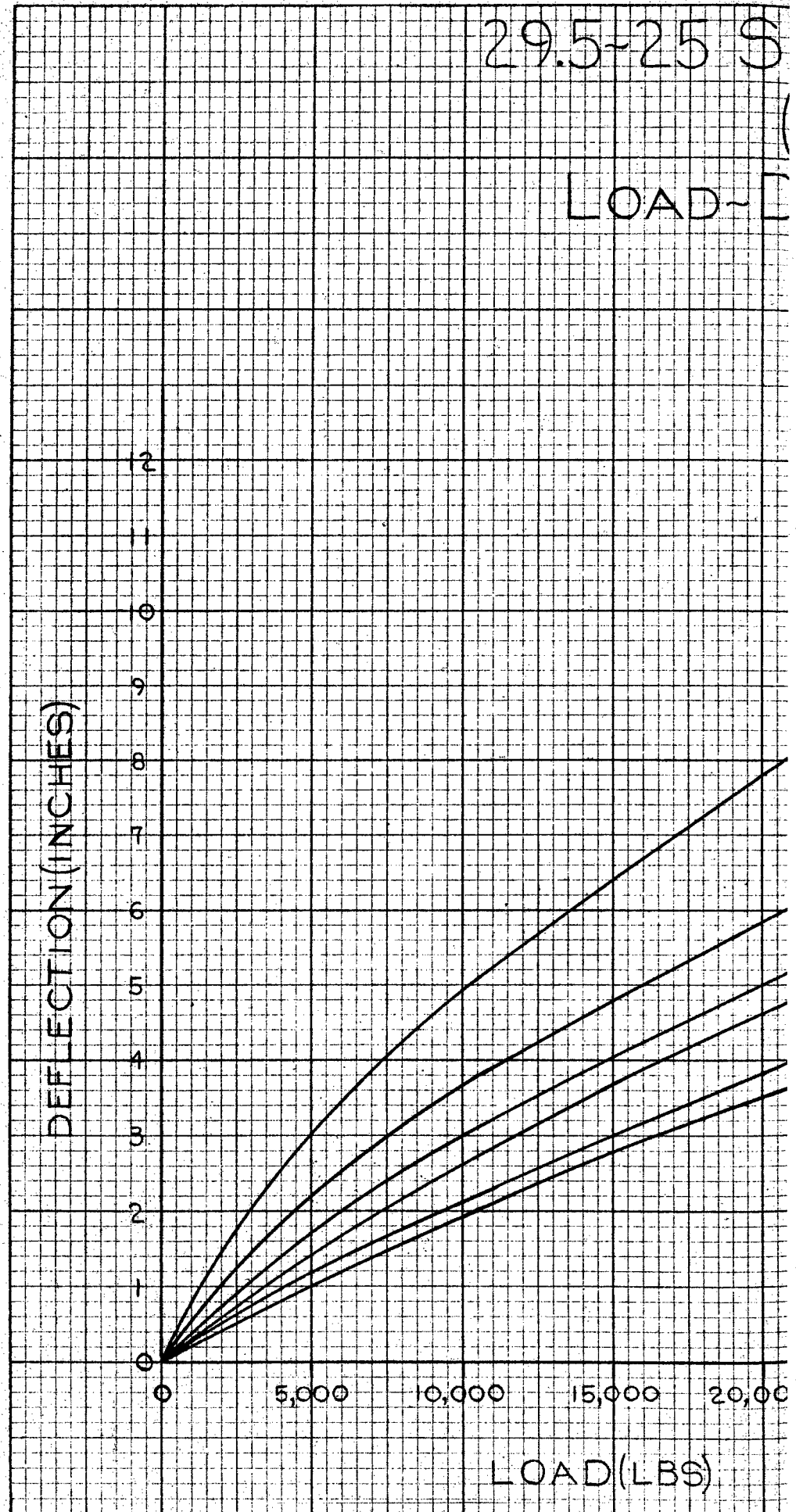
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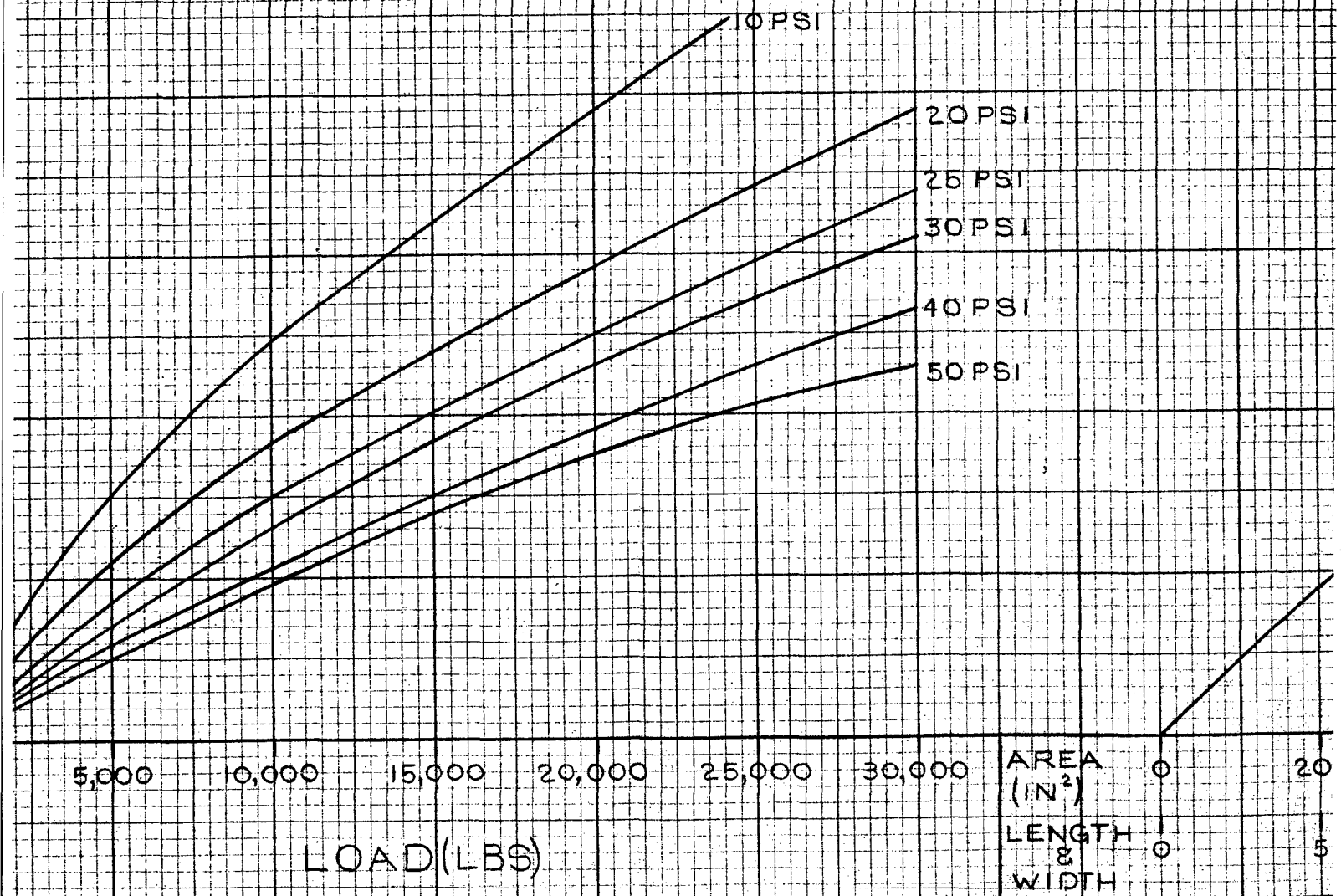
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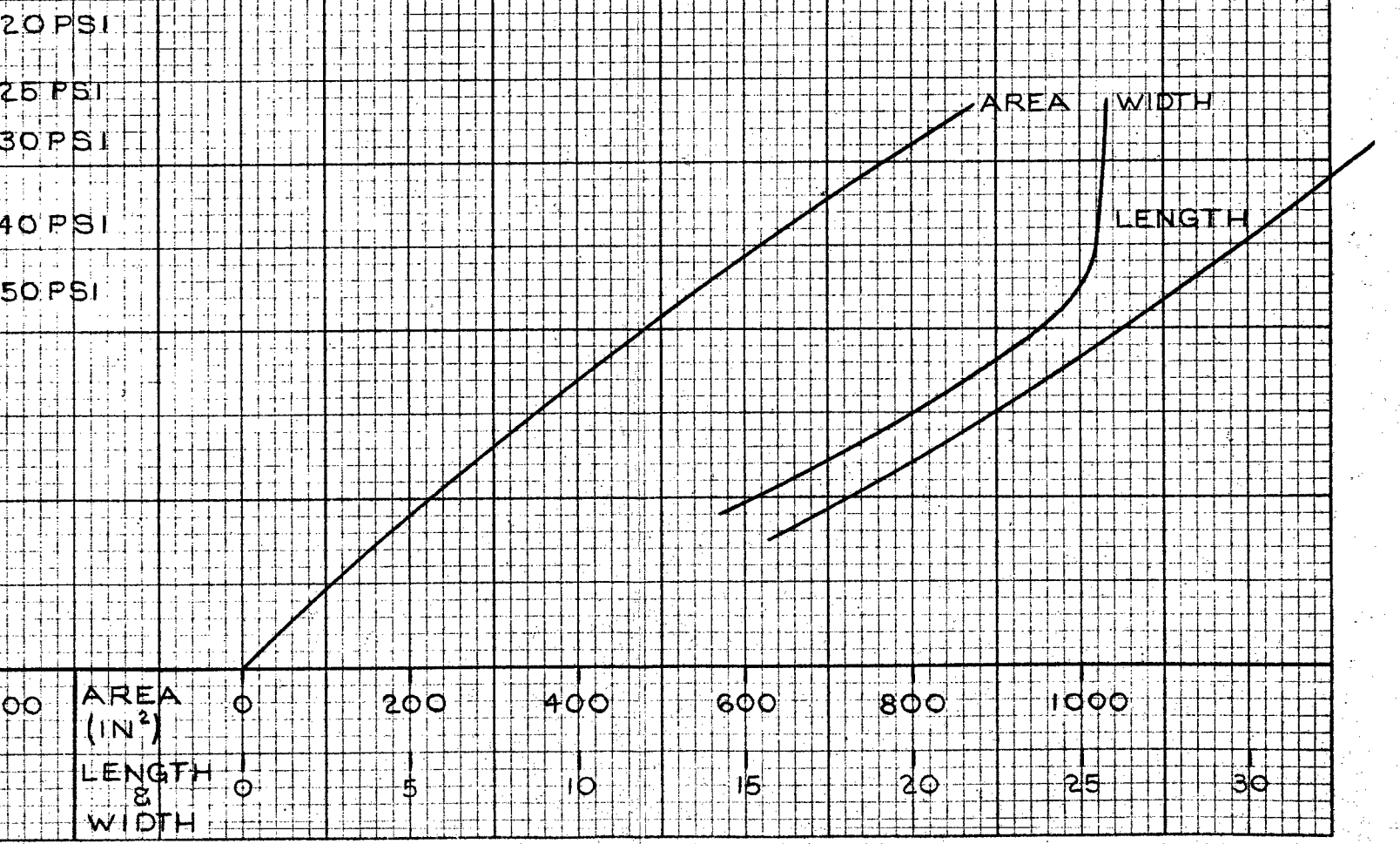


②

29.5-25 SUPER GROUND GRIP GC (WITH GROOVES) LOAD~DEFLECTION~CONTACT



UND GRIP GOER (6
OOVES)
N~CONTACT AREA



UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D		
<i>(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)</i>		
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3. REPORT TITLE Design, Development and Testing of Tires for 16-Ton GOER Vehicles 0200X		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report Sept 1960 - 1963		
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13. ABSTRACT Earthmoving tires were specifically developed for use on the GOER vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service. These tires are more suited to the requirements of the GOER Vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud.		

DD FORM 1473

NOV 68

REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rubber Tires Synthetic Rubber Tubeless Tires Non-Destructive Testing Traction Testing Highway Operation Tire Tread Designs Off-Road Mobility						

UNCLASSIFIED

Security Classification