MOTOR TRUCK SERVICE MANUAL

CTS-11 FOR L-LINE TRUCKS

AND

CTS-12 Supplemental Pages, for R-LINE TRUCKS ONLY

NOTE: Use CTS-11 Manual for R-LINE units other than shown in CTS-12 Supplemental pages.

L-LINE MOTOR TRUCKS SERVICE MANUAL CTS-11

This manual has been compiled in a simple, non-technical manner and every effort has been made to cover the most important items. It will provide a convenient reference source for the serviceman. Wherever possible, repetition of service instructions has been avoided by combining truck or unit models.

An index at the front of each group permits locating items covered in a particular Group. Where necessary, groups have been subdivided into sections. As additional data is compiled, new or revised pages will be issued. These should be inserted in their respective group and section.

IMPORTANT: Before starting any overhauling work, always remove the dirt that has accumulated around the parts to be disturbed. When parts are taken off, dirt not removed may fall into the units, contaminating the lubricating oil, and getting into bearings and other working parts. As dirt contains grit and abrasives, considerable unnecessary wear and reduction in efficiency is invariably the result.

Motor Truck Division

INTERNATIONAL HARVESTER COMPANY

180 NORTH MICHIGAN AVE. CHICAGO 1, ILLINOIS

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CHECKING LIST AND INDEX FOR R-LINE SUPPLEMENT TO THE CTS-11 L-LINE MOTOR TRUCK SERVICE MANUAL

NOTE: INSERT THESE R-LINE SUPPLEMENTAL PAGES IN THEIR RESPECTIVE SECTIONS IN THE CTS-11 SERVICE MANUAL

- The attached pages contain only those major units used on R-Line trucks which are not common to units used on the respective L-Line trucks.
- Only the service specifications and data for the R-Line major units are covered in these pages. Additional R-Line coverage will be released when available.

INTERNATIONAL HARVESTER

GENERAL INFORMATION GROUP

INDEX

WARRANTY

THE INTERNATIONAL HARVESTER COMPANY warrants each new INTERNATIONAL MOTOR TRUCK to be free from defects in material and workmanship under normal use and service, its obligation under this warranty being limited to making good at its factory any part or parts thereof which shall be returned to it with transportation charges prepaid, and which its examination shall disclose to its satisfaction to have been thus defective, provided that such part or parts shall be so returned to it not later than ninety (90) days after delivery of such vehicle to the original purchaser, and that at the time of such return, the said vehicle shall not have been operated in excess of five thousand (5,000) miles. This warranty is expressly in lieu of all other warranties expressed or implied and of all other obligations or liabilities on its part, and it neither assumes nor authorizes any other person to assume for it any other liability in connection with the sale of its vehicles.

This warranty shall not apply to any vehicle which shall have been repaired or altered outside of its factory in any way so as, in its judgment, to affect its stability or reliability, nor which has been subject to misuse, negligence or accident, nor to any commercial vehicle made by it which shall have been operated at a speed exceeding the factory rated speed, or loaded beyond the factory rated load capacity.

It makes no warranty whatever in respect to tires, rims, ignition apparatus, horns or other signaling devices, starting devices, generators, batteries, speedometers or other trade accessories inasmuch as they are usually warranted separately by their respective manufacturers.

INSPECTION OF NEW TRUCKS BEFORE DELIVERY

When trucks come off the assembly line at the factory they have already been given numerous unit inspections and in addition are subjected to a driving test and final inspection. Districts and Dealers should, however, recheck each truck prior to delivery to a customer. This is particularly advisable if trucks have been driven through or "double decked" by a drive-away company.

It is the responsibility of each District and Dealer to see that new trucks are delivered to users in a fault-free condition. This will mean a satisfied owner and will tend to eliminate unnecessary trips to the Service Station for minor adjustments during the warranty period.

The pre-delivery service at each District must include all of the operations listed below:

1. Clean and polish truck if necessary.
2. Lubricate chassis, and check oil in air cleaner.
3. Check lubricant level in transmission.
4. Check lubricant level in differential.
5. Check oil level in engine. Drain and refill if oil is not of proper viscosity for locality or season, or if truck has been driven any great distance.
6. Check cooling system for water.
7. Install battery, checking specific gravity and level of electrolyte.
8. Warm up engine and check operation of instruments and lights.
9. Tighten cylinder head and manifold nuts uniformly, using tension indicating wrench. (If truck has not been driven since leaving the factory, this operation is unnecessary.)
10. Adjust valve lash if necessary. Note: If head is tightened in operation (9), valves in overhead-valve engines will require adjustment.
11. Check and adjust carburetor for idle.
12. Check tire alignment on wheels. Correct if necessary. Tighten rim lugs.
13. Tighten all hub stud nuts.
14. Check front wheel alignment for toe-in of wheels.
15. Install tools, spare rim, and owner's manual, etc.
16. Give truck short road test, checking brakes, controls, and general handling, to assure that all are functioning properly.

INSTRUCTIONS TO OWNER AT TIME OF DELIVERY OF NEW TRUCK

As a rule, the purchaser's first impression is a lasting one, therefore it can easily be understood that trucks should be in perfect mechanical condition at the time of delivery. The operation and care of the truck should be thoroughly explained to the owner at this time.

It is suggested that the following instructions be given the purchaser at the time of delivery of the truck:

1. General information covering the construction and operation of the truck.
2. Advice as to the proper grade of lubricating oil. (See Lubrication Section.)
3. Explanation of the function, purpose, and maintenance of the oil filter.
4. Explanation of the function, purpose, and maintenance of the air cleaner.
5. Cover proper draining of the cooling system and the importance of using recommended anti-freeze solutions when necessary.
6. Importance of proper clutch pedal clearance in prolonging clutch life.
7. Cover lubrication of truck completely, pointing out hazard and costliness of neglect.
8. Advise owner to register such units as tires, batteries, electrical units, etc., with the local authorized dealers of that equipment.
9. Point out advantages of bringing truck to the International Service Station at specified intervals during the warranty period of inspection, at which time there may possibly be some minor adjustments advisable. These, if made, will aid in prolonging the life of the truck.
10. Stress the benefits of using only International Service parts and the advantages of having service work performed in International Service Stations or by International Dealers.

PRINTED IN UNITED STATES OF AMERICA

Form CT-6-MJ. 2500—11-16-49.
PRINTED IN UNITED STATES OF AMERICA

REPORT OF
MOTOR TRUCK COMPLAINT
INTERNATIONAL HARVESTER COMPANY

MAIL 5 COPIES TO GENERAL OFFICE, CHICAGO
MOTOR TRUCK SERVICE SECTION

SERIOUSNESS OF FAILURE IS BASED UPON THE NUMBER OF COMPLAINTS RECEIVED. REPORT EACH CASE UNTIL YOU HAVE BEEN INFORMED OF REMEDY BY BULLETIN OR GENERAL LETTER. IF REMEDY FAILS, EACH CASE MUST BE REPORTED.

DISTRICT OFFICE District DATE 6-8-49

BRANCH ______ IS REPLY DESIRED?

WHEN REPORTING ON UNITS SUCH AS CAB, AXLE, TRANSMISSION, ETC., SERIAL NUMBER OF UNIT MUST BE GIVEN.

UNIT SERIAL NO. Be sure to give this information.

COMPLAINT DETAILS Engine - loss of power and failure to start when hot.

DISTRIBUTION

SUPERVISOR OF INSPECTION	6TH FLOOR, G. O.
SERVICE ENGINEER	FT. WAYNE
SALES SERVICE SECTION	FT WAYNE
CHIEF INSPECTOR	FT. WAYNE WORKS
CHIEF INSPECTOR	INDIANAPOLIS WORKS
CHIEF INSPECTOR	SPRINGFIELD WORKS
SERVICE PARTS DEPT.	FT. WAYNE
WORKS MANAGER	METROPOLITAN BODY CO.

DELIVERY DATE 7-3-48 TOTAL MILES TO DATE 14,289

OWNER Name CITY Address STATE ______

MODEL L-210 WHEELBASE 149" ENGINE NO. RD-450,20977 (INCL. PREFIX & SUFFIX LETTERS) CHASSIS NO. 8675

THE FOLLOWING INFORMATION MAY BE OMITTED IN CASE OF FAILURE ON MINOR UNITS SUCH AS CABS, HORNS, RADIATORS, WINDSHIELD WIPERS, GLASS, SHEET METAL, INSTRUMENTS, ETC. BUT ON MAJOR UNITS SUCH AS AXLES, ENGINES, CLUTCHES, TRANSMISSIONS, PROPELLER SHAFTS, FRAMES, WHEELS, ETC., FILL OUT COMPLETELY.

STRAIGHT TRUCK — TRACTOR & TRAILER

MAX. PAYLOAD ______ MAX. PAYLOAD 32,000 GEAR RATIO 6.5 - 8.86-1

TOTAL GROSS WT. ______ TOTAL GROSS WT. 51,000 TIRE SIZE 10:00x20 (FRONT) SINGLE ______ DUAL 10:00x20 (REAR)

TRUCK BODY TYPE ______ TRAILER BODY TYPE Closed COMMODITY HAULED Misc. Freight

TRUCK BODY SIZE ______ (LENGTH—WIDTH—HEIGHT) TRAILER BODY SIZE 32' Tandem Axle (LENGTH—WIDTH—HEIGHT) WHO MOUNTED BODY Trailmobile

LOCAL OR LONG DISTANCE Long Distance TYPE OF ROADS Paved MAX. SPEED 50 M.P.H. AVER. SPEED 40 M.P.H.

WHO MAINTAINS SERVICE IHC and Owner COST OF MATERIAL ______ LABOR ______ GRATISED $ None

WHAT ALTERATIONS HAVE BEEN MADE BY DISTRICT OFFICE, DEALER OR CUSTOMER ON ANY PART RELATED TO THE FAILURE?

INVESTIGATED BY Name POSITION ______

REMARKS ______

EXAMPLE

WE WILL WELCOME SUGGESTED REMEDIES WHICH HAVE BEEN TRIED AND PROVED SUCCESSFUL.

Use Reverse Side for Additional Remarks.
A Separate Letter Complicates and Delays Action.

SIGNED Signature
SERVICE MANAGER OR FOREMAN

APPROVED Signature
DISTRICT MANAGER

A-23214

MOTOR TRUCK COMPLAINT FORMS

Two forms, CT-6 and GF-70, are used to provide a continuous flow of information from the Districts through the General Office to the various Works and Departments regarding the performance of our product in service and as a final check on the condition of our product as received by the Districts.

This information is of utmost importance to our Manufacturing and Engineering Departments in maintaining the high quality of our Product. Therefore, the task of guarding the quality of our product rests largely with our District Organization. This task can best be performed by the District reporting complaints on the regular complaint forms.

All complaints, both CT-6 and GF-70 forms, received by the Motor Truck Service Section, Chicago, are given wide circulation through our Engineering and Manufacturing Departments and to interested parties in our Chicago General Office. These complaints provide a rapid and accurate flow of information to our Works Inspection Departments so that necessary corrective action can be taken to eliminate the cause of such complaints promptly.

The necessity for a remedy is based entirely on the seriousness of the complaint. The seriousness of a complaint is based on the number of those complaints received.

The following instructions and suggestions are for your assistance in making out and submitting these forms:

Motor Truck Complaint form CT-6 is to be used in cases of serious failures where assistance is solicited by the District in the solution of a pressing service difficulty for which the District is unable to find an answer. This form should also be used in reporting complaints where the complaint is contributed to by loads or operating conditions and the information requested on the form is necessary for the complaint to be properly analyzed.

Product Report form GF-70 is to be used largely during the warranty period in reporting failures or complaints on current models on which no immediate assistance is needed. This form should also be used in reporting failures or complaints on new parts and assemblies from our Service Parts Department and in reporting unfavorable customer reaction to design or material, unsatisfactory performance or difficulty of servicing our trucks.

1. ALL COMPLAINTS concerning which the territory has not been advised of a remedy, must be reported. In other words, you are to continue the reports on all trouble until advised of a remedy or correction.

2. Complaints concerning which the territory has been advised of a remedy should not be reported; except in cases where the remedy itself fails; and except in such cases where the Service Bulletin announcing the remedy advises that Complaint Forms are necessary in order to obtain credit from the Vendor. Then so state under "Remarks."

3. Complaints on each unit must be covered on a separate and proper Complaint Form except in the case of trucks where the same unit fails on several trucks of the same fleet; you may use the same form but list the chassis, engine and unit serial number of each truck involved.

4. It is important that the unit serial number be given in the space provided on form CT-6 Bulletins have advised the location of the serial numbers on the various units. The major part numbers affected should be shown in the space provided on GF-70 forms,

5. State the complaint clearly on form CT-6 under the heading Complaint Details and on form GF-70 under the heading Complaint. For instance, if you are reporting the failure of a "Rear Axle Shaft" state "Rear Axle Shaft Failure" (left or right). Do not just state "Rear Axle Failure."

6. If you believe certain material should be returned for inspection, state under "Remarks" that the material is being held, and hold material for thirty days after acknowledgement of complaint has been received, unless disposition is given in the meantime. Hold parts covered by GF-70 forms for 30 days after submitting form.

7. All material returned should be properly packed and tagged so that it can be identified and, in addition, should bear the "Returned for Inspection" tag, Form CTS-1, filled in properly and completely. (See General letter MT No. 11, 4-21-49).

Form GF-70-J 100M—9-1-49. PRINTED IN UNITED STATES OF AMERICA

INTERNATIONAL

MOTOR TRUCK PRODUCT REPORT

DISTRIBUTION

SUPERVISOR OF INSPECTION	4TH FLOOR G O
SERVICE ENGINEER	FT WAYNE
SALES SERVICE SECTION	FT WAYNE
CHIEF INSPECTOR	FT WAYNE WORKS
CHIEF INSPECTOR	INDIANAPOLIS WORKS
CHIEF INSPECTOR	SPRINGFIELD WORKS
SERVICE PARTS DEPT	FT WAYNE
WORKS MANAGER	METROPOLITAN BODY CO

COMPLAINT SPEEDOMETER CABLE BROKEN DUE TO CABLE HAVING BEEN INSTALLED WITH A SHARP KINK AT FLYWHEEL HOUSING.

REMEDY: NEW CABLE ASSEMBLY INSTALLED AND PROPERLY ROUTED.

MAJOR PART NO. AFFECTED 75207-H

DISTRICT OFFICE DISTRICT

SIGNED NAME SERVICE FOREMAN
TITLE

DATE 1-15-49

SERVICE MILEAGE
(ON PART INVOLVED) 840

TYPE OF SERVICE:

LONG DISTANCE	X
DUMP	
OFF HIGHWAY	
MULTISTOP	
STRAIGHT TRUCK	X
TRAILER — SEMI	
TRAILER — FOUR-WHEEL	
OTHER	

TRUCK MODEL L-160

CHASSIS NO. 67567

ENGINE MODEL SD-240

ENGINE NO. 231897

See Reverse Side for Instructions

EXAMPLE

INSTRUCTIONS

1. Use this form to report any type of failure or complaint on current models on which no immediate assistance is needed. Do not expect an acknowledgment.

   Use CT6-M complaint form to report on matters where assistance is necessary or where an acknowledgment is expected.

2. Mail five (5) copies immediately to:

   INTERNATIONAL HARVESTER COMPANY
   Motor Truck Division
   Service Section
   3rd Annex
   180 N. Michigan Ave.
   Chicago 1, Illinois

3. Retain sufficient copies for your District Office files.

4. Do not report failures on unimproved parts or assemblies when an improvement has already been announced to the field by bulletin or otherwise.

A-23215

8. It has been the practice in the past for the Servic Supervisor to make out the CT-6 forms and submit them to the District Manager for his signature. This has caused some delay where the Service Supervisor is in charge of both motor truck and general line service, as it has been necessary for him to spend much time on the territory, resulting in the Complaint Forms not being made out and submitted promptly after the failure occurs. The logical time to determine if a failure should be covered on a CT-6 or GF-70 and to gather information for the Form is when the truck is in the Service Station and the repairs are being made. Therefore, when the Service Supervisor is away, the Service Foreman should gather the information and make out the CT-6 or GF-70 form, in order that they can be submitted as quickly as possible after the failure occurs.

9. Much information, which would be valuable in assisting the various Departments in diagnosing and developing remedies for the complaint, can and should be given under the caption "Remarks" or on an attached sheet. For instance: a clear description of the failure; the Service Supervisor or the Service Foreman's opinion of the cause of the failure; his idea of a remedy, if any; the results of his remedy if applied; any local climatic conditions that are peculiar and have bearing on the complaint; any unusual operating conditions that might play a part in the complaint; and, in short, any information, additional to that requested on the form, which has any bearing on the complaint, should by all means be given. This means that a thorough investigation of the complaint should be made by the Service Supervisor or Foreman before attempting to make out the Complaint Forms.

10. In the past it has been the general practice for the Branches to make out CT-6 forms and forward them to the District for the Service Supervisor to check and for the District Manager's signature. This, in some instances, has caused considerable delay in submitting these forms to the Chicago Office. We suggest that the Service Station Foreman at each Branch should make out the Complaint Forms and submit them to the Branch Manager for signature and forward direct to the Chicago Office. An extra copy, however, should go to the District office for the District Manager's files. GF-70 forms may be made out and signed by the Service Supervisor, Service Station Foreman and A & H Foreman. Branches should send one copy of each GF-70 form to the District office for the District Manager's files.

11. Copies of the complaint reports, GF-70 and CT-6, are to be distributed as follows:

    5 copies to Chicago Service Section.
    1 copy for District Manager.
    1 copy for Service Station files.

12. The District Manager should review his complaint file monthly with the Service Supervisor and personally follow up with the respective Service Divisions of the Chicago Office all cases where no remedy has been provided.

We cannot emphasize too strongly the importance of making prompt and complete reports on all complaints that should be brought to the attention of the Engineering, Manufacturing or Sales Department at Chicago.

Examples of CT-6 and GF-70 Complaint Forms properly filled out are illustrated on preceding pages.

Materials Returned for Inspection

RETURNED FOR INSPECTION TAG, FORM CTS-1 is especially prepared and adapted to portray all necessary information if and when properly filled in. It is designed to be used on all shipments of materials sent in for inspection other than surplus repairs.

The following special instructions must be adhered to in the use of the card:

1. Obsolete or defective parts must not be returned unless authority is granted.

2. The CTS-1 Tag must be attached to all shipments of materials sent in for inspection other than surplus repairs or exchange units such as crankshafts.

3. Shipping charges must be prepaid.

4. All blank spaces on tag must be filled in to portray necessary information.

5. Tag should be made out in ink or hard pencil to avoid obliteration during shipment.

6. Attach tag to parts rather than to package to avoid loss when unwrapping.

7. Refer to date of CT-6 Complaint Form or GF-70 Form if such has been issued.

8. Where possible, report unit serial numbers of such units as Engines, Cabs, Transmissions, Axles, etc., when reporting concerning these units.

To avoid the necessity of writing separate letters, it is generally possible to include all general information under the caption "REMARKS."

VEHICLE SPECIFICATION CARD

LOCATED ON DASH INSULATOR PANEL, ABOVE CLUTCH AND BRAKE PEDALS ON MODELS L-160 AND UP

VEHICLE SPECIFICATIONS

DESCRIPTION	SERIAL NO.	CODE	VARIATIONS
L181 142 WB 19000 GVW		11802	1
BLD 269 ENGINE		1209	C
DELUXE OIL FILTER		1250	
F51 OD TRANS		1307	AD
TWO SPEED AXLE		1412	BC
6166/8577 REAR RATIO		1446	B
20 GAL UNDERSKIRT FUEL TANK		1501	
SEE BELOW FOR PAINT			
REGULAR CAB		1603	A
REAR VIEW MIRROR EXT TYPE		1669	A
SPOKE TYPE WHL W/700T RIM FRT		1728	E
900X20 10 PLY TIRES FRT			
SPOKE TYPE WHL W/700T RIM RR		1928	F
900X20 10 PLY TIRES RR			
GOODRICH TIRES			
FRAME REINFORCEMENT		0102	ACDG
VACUUM LINE AIR CLEANER		0418	
S25 3YD 9X6 1/2 DUMP BODY		3277	
720 ANTHONY HOIST		3092	
BODY AND HOIST TO BE FURNISHED			
AND MTD BY TECO ORDERED BY O/D			
PAINT ENTIRE TRUCK 90 ORANGE			

EXAMPLE

A new procedure for handling Service Parts has been placed in operation at the International Motor Truck Service Parts Department. With this new system in operation, it is expected that the vehicle owner will realize many benefits from a service standpoint, particularly when ordering replacement parts for his truck.

The system consists of assigning code numbers to the units included in the vehicle, such as: engine, transmission, cab, rear axle, wheels, etc. This same code number is used during the manufacture of the vehicle and will be further carried over into the parts catalogs which apply to the particular model trucks. By this means, a common language has been set up for all parties involved in the design, the use, and the servicing of this particular vehicle.

Code numbers are assigned only to those units to which the customer has an optional choice. The code numbers assigned to the units on the L-160 Models and up have been printed on a "Vehicle Specification Card" which is included with the truck and is located on the dash insulator panel directly above the clutch and brake pedals. The parts catalogs are subdivided into sections identical with code numbers shown on the "Vehicle Specification Card."

When ordering parts for the truck, it is important to include with the order the information contained on the "Vehicle Specification Card" which pertains to the unit for which the parts are being ordered. For example, if it became necessary to order a countershaft for the transmission on the vehicle shown on the sample "Vehicle Specification Card" it would only be necessary to indicate on the order that a countershaft for the L-181, F-51 OD transmission, under code number 1307 AD was needed. From this information it can be quickly determined just which part should be supplied.

The "Vehicle Specification Card" will prove of great value to the customer when entering the Service Station for Service work, since reference to the card will indicate to the Service Station just what units are included with the vehicle and will put them in a position to render the best possible service.

Be sure to keep the "Vehicle Specification Card" with the vehicle at all times.

FREE INSPECTION DURING WARRANTY PERIOD

I. First Inspection During Warranty Period

A. Mileage, 1000 miles or 30 days, whichever first occurs.

Note: It is recommended that the first inspection at 1000 miles or 30 days consist of the following checks and adjustments, because this will be the first opportunity the foreman will have to show the new customer the service facilities and to sell him in the advantages of International Truck Service.

B. Checks and adjustments:

1. Distributor point gap.
2. Tighten cylinder head nuts uniformly (all engines).
3. Adjust valves (valve-in-head only).
4. Tighten manifold and carburetor flange nuts (all engines).
5. Check carburetor idle adjustment.
6. Check oil pressure, generator charging rate, and heat indicator.
7. Check clutch pedal free movement.
8. Change engine oil (charge for oil).
9. Lubricate chassis (charge, if it was former practice).
10. Check lubricant level in transmission and in differential.
11. Check rim clamps, nuts, disc wheel studs and axle shaft studs and nuts.
12. Check brake pedal free movement.
13. Check window regulator, windshield wiper, lights, and horn.
14. Short road test noting general performance and handling.

II. Final Inspection During Warranty Period

A. Mileage 4000 to 4500 miles or within 90 days.

Note: This final inspection is recommended in order to give the truck a thorough check before expiration of warranty, and to enable the foreman to sell the customer on the importance of preventative maintenance during life of truck.

B. Checks and adjustments:

1. Check spark plug gaps -- adjust if necessary.
2. Check distributor point gaps -- adjust if necessary.
3. Check ignition timing -- correct if necessary.
4. Tighten cylinder head.
5. Adjust valves (all engines).
6. Tighten manifold and carburetor flange nuts uniformly.
7. Check fan belt tension.
8. Check carburetor idle adjustment.
9. Check cooling system for leaks.
10. Check air cleaner -- clean and change oil in sump if necessary.
11. Clean fuel pump sediment bowl (renew gasket).
12. Check engine for oil leaks.
13. Change engine oil (Charge for oil). (If condition of oil indicates necessity for new filter cartridge, notify customer).
14. Check oil pressure, charging rate, and heat indicator.
15. Check governor control.
16. Check clutch pedal free movement.
17. Check brake pedal free movement.
18. Check fluid level in master cylinder.
19. Lubricate chassis (charge if it were former practice).
20. Check lubricant in transmission and differential (charge for grease, if added).
21. Check rim clamp nuts, disc wheel nuts and studs and axle shaft nuts.
22. Check battery water level, cables and mountings.
23. Check window regulators, windshield wipers, lights, and horn.
24. Make a short road test noting general performance and handling -- make necessary adjustments.

COLD WEATHER RECOMMENDATIONS

Important

There are a few simple precautionary measures which should be taken in preparation of a truck for cold weather operation. Instructions should be given truck owners covering this procedure.

1. Engine

Selection of proper engine lubricating oil demands consideration of two important factors -- namely, easy starting during low atmospheric temperatures, and adequate engine lubrication after the engine is placed in service.

Lighter viscosity oils facilitate cold-weather starting and also provide better immediate lubrication as the engine starts. They do not, however, provide adequate lubrication under sustained higher engine speeds or severe service. Increased oil consumption can also be expected when using lighter viscosity oils.

Consideration must therefore be accorded the cold weather housing facilities for the idle truck, the service in which the truck is engaged, and the selection of higher viscosity oils which have better free-pouring characteristics at low temperatures.

In consideration of the foregoing, the following general recommendations are made:

MODERATE SERVICE (Trucks operating in multi-stop or other service where sustained higher engine speeds will not be encountered.)

ENGINE	TEMPERATURES 90°(F.) and up *	32°(F.) to 90°(F.)	HO°(F.) to 32°(F.)	-10°(F.) to +10°(F.)
SD	SAE-30	SAE-30	SAE-20W	SAE-10W
BD	SAE-40	SAE-40	SAE-20W	SAE-10W
RD	SAE-40	SAE-40	SAE-20W	SAE-10W
R-6602	SAE-40	SAE-40	SAE-20W	SAE-10W

*See Hot Climate — High Speed Instructions, see below

For temperatures lower than minus 10°(F.), use SAE-10W plus kerosene. (SAE-10W may be safely diluted with colorless kerosene up to 30%). Mix kerosene thoroughly with the oil before adding to the engine.

Hot Climate — High Speed.

For trucks operating on highway or other services demanding sustained higher engine speeds use engine lubricating oils having a viscosity of as near SAE-50 as possible (SAE-40 for SD Engines) in keeping with the starting ability.

Note: High viscosity oils are available which also have very good cold-pour characteristics.

2. Electrical

(a) Clean and adjust spark plugs. (See "Electrical System.")

(b) Check all wiring for loose or broken connections. Make necessary replacements.

(c) Clean and tighten battery cable terminals.

(d) Check battery for being fully charged and electrolyte to star level in cell covers. (Note: During cold weather, the battery must not be allowed to stand after adding distilled water without running engine to charge battery. This is important because otherwise the water will not be thoroughly mixed with the electrolyte, and freezing may result.)

(e) On models having an adjustable third-brush generator, the charging rate should be adjusted to meet the demands of the cold weather operation.

3. Cooling System

(a) Drain and flush cooling system to remove all sediment and foreign material. (Note: The "reverse flushing" system is the most effective method and can be performed either in your own service station or by reputable radiator repair shops.)

(b) Anti-freeze solutions of known value and manufacture only should be used. Specific gravity checks should be made periodically to assure protection from freezing. (Note: Salts or chlorides, sugar, glucose, honey, fats, etc., should not be used as an anti-freeze.)

Where anti-freeze solutions are not used and cooling system is to be drained, you are cautioned to refer to instruction books for location of drain cocks or plugs on engine blocks, radiators, or oil coolers.

(c) If the thermostat has been removed from the engine, it should be reinstalled after ascertaining that it is in good operating condition.

4. Winter Fronts

The use of an efficient winter front will enable the operator to better control the operating temperature. It will also result in higher under-hood temperatures, effecting more efficient operation of the engine, and will make it less susceptible to sludge formation and condensation.

5. Rear Axle and Transmission

Severe cold weather may make a change of lubricant advisable in the transmission and differential. A lubricant of lighter viscosity will provide better lubrication to the moving parts and will create less friction and resistance to the movement of the various gears, shafts, etc.

6. Propeller Shaft Bearing (not 6-wheel units)

The propeller shaft center bearing on International trucks should be lubricated with a medium short fibre wheel bearing grease having the following characteristics: cold-milled, sodium-soap content, having a work penetration consistency of 250 that will not break down below 300.

BALL AND ROLLER BEARING MAINTENANCE

Important

In order to assure bearings being free of rust, dirt, or damage, the following procedure relative to storage, handling, and installation is recommended:

1. Storage

(a) Stock only limited quantity of bearings. Bearings should be ordered and stocked in quantities in keeping with requirements consistent with Branch Zone Repair Orders.

This will assure fresh stock and will guard against obsolescence.

(b) Store ball and roller bearings in their original wrappers or cartons. Do not remove protective coverings until ready to use the bearing.

(c) If necessary to inspect bearings in stock, they should be again carefully wrapped to guard against dirt.

(d) Bearings which have been allowed to remain unwrapped must be washed, relubricated, and rewrapped. This does not apply to prelubricated bearings.

(e) Store bearings in a cool and dry place. A hot storage space will cause the protective lubricant to melt and drain off the bearings. A damp storage space will permit moisture to collect on the bearings, resulting in rust and corrosion. Water or moisture will ruin a bearing.

2. Delivery of Bearings to Customer or to Service Station.

(a) Deliver bearings in original cartons or wrappers.

(b) Handle bearings carefully. Rough handling will damage containers and permit dirt and foreign matter to enter bearing.

3. Cleansing and Lubrication of Bearings

(a) Use clean kerosene or Stoddard Solvent in a clean container.

(b) Use clean rags or towels, and never use waste. Lint from waste may enter bearing.

(Note: Suitable wheel bearing cleaner equipment is available, which will facilitate bearing cleansing.)

(c) Dip bearing in kerosene several times, rocking bearing race rings slowly to dislodge grease from ball sockets.

(d) Spin bearing while repeatedly dipping into kerosene. Continue operation until bearing runs smoothly and quietly or until it is clean and ready for inspection.

(e) If bearing is found satisfactory, dip in a neutral oil or thin grease and wrap. (Note: Suitable wheel bearing grease packer equipment is available, which will produce excellent results.)

4. Removal and Installation of Bearings

(a) Shafts or housings must be clean and free from burrs.

(b) Use properly arranged press plates or arbors for installation or removal of bearings.

In pressing bearings into place the pressure or load should be so applied that it will not be transferred through the balls.

For example, if bearing is applied to or removed from shaft, pressure should be applied to inner bearing cone.

If bearing is being installed in or removed from a housing or case bore, pressure should be applied to outer bearing cup.

(c) Do not hammer on bearings. Lead or babbitt hammers may chip off and allow pieces to lodge in bearing. Wooden hammers may leave splinters in bearings. Steel hammers will chip, crack, or Brinell the bearing.

(d) If necessary to heat bearing for installation or removal, use a light or medium-weight oil heated to 225° (F.). Allow bearing to stand in this oil until thoroughly heated.

(e) Upon installation of bearing, lubricate bearing seat with light oil.

(f) Apply steady pressure. If bearing sticks or binds, ascertain cause. Correct fault and then proceed with operation. A bearing started in a cocked position will bind.

Burrs in housings or on shafts will cause severe binding and sticking.

Bearing should rest squarely against shoulder or in recess.

(g) Bearing should roll freely after installation unless individual specifications call for a preload. Test bearing for bind or drag by holding bearing outer race between thumb and finger, and test for side play. (A radial clearance of .0001" will produce side play of approximately .005" to .006".) Shafts mounted in bearings should rotate freely after installation unless individual specifications call for a preload. Test by revolving shaft assembly.

5. Intermixing of Component Parts -- Roller Bearings

Wherever possible, intermixing of roller bearing component parts should be discouraged. Therefore, where possible, IH parts should be used to service IH assemblies, Timken parts to service Timken assemblies, etc.

STEEL AND ITS HEAT TREATMENT

To the average man, steel means but little more than something hard, heavy, and strong, and capable of being formed into practically any desired shape. This is quite true as far as it goes. However, there are many conditions that determine and control the degree of hardness and of strength.

It is the object of this discussion to tell in non-technical terms as nearly as possible just how and what these determining and controlling factors are, how they are applied, and the results accomplished thereby.

In automotive manufacture it is absolutely essential that the very best steels available be used, and in their respective classes. One part will require extreme hardness to resist abrasion or wear, another will require extreme toughness to resist shock and vibration, and to support heavy loads, another must develop great powers of flexibility, yet must resist bending, etc. In these various uses, the parts are subjected to different kinds of stresses, both "static" and "dynamic" (dead quiet and vibratory, respectively) in combination with their loads carried under compression or in tension, or subjected to transverse, shearing or torsional stresses.

Before selecting a steel for a given purpose, attention must be given to its requirements in the finished part, and in the completed mechanism in operation. The most commonly known and used steels contain in addition to their ferrite or pure iron base either one or more of the following elements -- carbon (the most important), nickel, chromium, vanadium, molybdenum, and tungsten, each being included either separately or combined with others in order to impart the distinctive properties of the included elements. It should be noted that upwards of 95 percent of all steel is pure iron. Castings, either grey iron, malleable iron or steel, originate with pure iron as their base.

In the manufacture of steels, the inclusion, in varying previously determined percentages of these elements, results in, with the proper heat treatment, definite closely predetermined physical properties. For example, one effect of chromium in steel is to increase its hardening power.

A steel rendered hard by the presence of chromium is far less brittle than one rendered hard by the presence of carbon alone. Hence, hardness combined with toughness may be secured by reducing the carbon and increasing the chromium content. However, chromium alone (or any other alloy) in the absence of carbon has no hardening power. The presence of both nickel and chromium in steel makes it highly resilient and ductile and gives it greater hardness and better wearing qualities than plain carbon steel. Nickel-chromium steels are especially valuable for parts to be hardened and tempered, as the finer structure thus produced has greater shock-resisting power than that of plain carbon steels. These are all valuable elements and there are doubtless many others equally as valuable as yet undiscovered.

The presence of phosphorus and sulphur is injurious to steel and must be guarded against. These impurities unite with other elements and form compounds which render the steel extremely brittle and liable to break. Phosphorus and sulphur inclusions are guarded against by their removal during manufacture, and by the inclusion of other elements which unite with these impurities to form harmless compounds, thus counteracting their bad effects.

The hardening power of steel rests almost entirely with its carbon content. As for example, a steel containing a 0.40 to 0.50 percent carbon (4/10 to 5/10 of 1 percent) is capable of becoming much harder than one containing 0.10 to 0.20 percent. The carbon content is often referred to as forty or fifty points carbon, a point being equivalent to 1/100 of 1 percent.

The heat treatment of steel consists of annealing, hardening and tempering.

Annealing

Annealing consists of heating above the "critical range," then cooling slowly, for the purpose of refining the grain, softening the steel to machinability and relieving the internal strains set up in the steel by forging and hammering, these strains sometimes amounting to several thousand pounds per square inch.

Hardening

Hardening consists of heating above the critical range and cooling quickly, as by quenching in oil or water, the degree of hardness depending upon the carbon content of the steel and the severity of the quench.

Tempering

Water quenching is more severe than oil quenching and is frequently followed by tempering or drawing to reduce the brittleness imparted by the severity of the quench, this brittleness being ever attendant to the high degree of hardness thus obtained.

The tempering heat must not rise above the critical range, or the effects of the previous heat treatment will be destroyed and the refined crystalline structure will be obliterated, becoming more coarse and suffering a considerable loss of hardness.

By critical range is meant the range above and between the critical heating point, or point of "decalescence," and the critical cooling point, or point of "recalescence." The presence of these critical points in the heating and cooling of steel is a phenomenon and is explained as follows:

While heating, the steel uniformly absorbs heat. Up to the decalescence point all of the energy of the heat is exerted in raising the temperature of the steel. At this point the heat taken in by the steel is expended, not in raising the temperature of the steel, but in work which produces the internal changes here taking place, the dissolving of the carbon in the iron. Therefore, when the heat is exhausted in this manner, the temperature of the piece, having nothing to increase it, will remain unchanged for a time, or may even fall slightly, owing to surface radiation, after which it will again increase.

When the piece has been heated above the decalescence point, and is allowed to cool slowly, the process is reversed. Heat is then radiated from the piece. Until the recalescence point is reached the temperature falls. At this point also the structure of the steel undergoes a change, the carbon crystallizes out of the iron, and the energy previously absorbed is converted into heat. This heat set free in the steel supplies, for the moment, the equivalent of that being radiated from the surface, and the temperature of the piece ceases to fall, remaining stationary, and should the heat resulting from the internal changes be greater than that of surface radiation, the resulting temperature of the piece will not only cease falling, but will actually rise slightly at this point. In either event the condition exists only momentarily and when the carbon and iron constituents have resumed their original relation, the internal heat decreases, and the temperature of the piece falls steadily, due to surface radiation.

From the foregoing, it is evident that there is a definite temperature at which any steel should be hardened, and that that temperature is dependent upon or governed by the percentage of carbon in the steel; also, that a great loss occurs of both labor and material unless the hardening is carried out at that temperature. Of greatest importance is the necessity of rigid inspection and tests to assure properly heat-treated parts.

These critical points are determined and the temperature controlled by the use of recording pyrometers and other apparatus. The recording pyrometer presents graphically a temperature curve showing the exact temperature of the decalescence and recalescence points, the decalescence point being recorded on the chart while the piece being tested is in the furnace, and the recalescence point being recorded after removal of the piece from the furnace and in the process of quenching. In obtaining these records the thermo-couple, or the furnace end of the pyrometer, is securely clamped to the test piece to insure that the reading will be that of the temperature of the test piece and not that of the atmosphere of the furnace.

Casehardening or Carburizing

Carburizing, carbonizing or casehardening are names applied to the process wherein a piece of low-carbon steel is packed in a carbonaceous material such as bone or leather, or a commercial carburizing material and heated for a number of hours, just above the "critical range" of the steel, or above its point of decalescence, thereby causing the low-carbon steel to absorb carbon on the outer surface for a depth directly dependent upon the number of hours it is heated. Under such conditions, a carbonized case is produced which is capable of responding to ordinary hardening or tempering operations.

The object of casehardening is the production of a hard wearing surface with a backing or core of tough, low-carbon steel. There are two results gained by its use, the first of which is the production of the part from more easily machined steel of cheaper grade; and second, the production of the part from a cheaper steel which is superior to a part produced from high-carbon steel, high enough in carbon to have the proper surface hardness, in that the casehardened surface has the hardness to resist wear, backed by a low-carbon core which has the toughness to resist shock, two factors of vital importance in the manufacture of motor truck parts, such as piston pins, camshafts, gears, etc.

Upon receipt of each shipment of steel from the steel mills, a representative number of specimens are prepared for chemical analysis and for tests for physical properties. All steels must meet the requirements of the standards for their respective classes, both as to chemical analysis and physical properties, as specified by the Society of Automotive Engineers, both before and after heat treatment. The inspection and tests from the rough stock are precautionary measures to prevent defective material from getting into production, from which it would be impossible to obtain the proper results by heat treatment. The inspection and tests made on parts after having been machined and heat-treated are for the direct protection of the quality of the product.

The most generally used tests, standardized and authorized by the S. A. E., are the Brinell hardness test, the Shore Scleroscope hardness test, and the Tensile test. The Brinell and Shore tests are check tests and for hardness only, while the Tensile test gives a complete history of the physical properties of the specimen tested as follows:

Modulus of elasticity.

The elastic limit in pounds per square inch.

The tensile strength in pounds per square inch.

The percentage elongation.

The percentage reduction of area.

Brinell Test

The Brinell test is commonly made with a hydraulic testing machine in which a steel ball of ten millimeter diameter is pressed into the test piece by a load of three thousand kilograms. The diameter of the impression the ball produces in the test piece is then measured and checked against a standard. Thus an impression four millimeters in diameter indicates softer steel than a diameter of three and one-half millimeters.

The Brinell test is definitely related to the ultimate strength of the material.

Scleroscope Test

The Shore Scleroscope test is made with a small instrument which drops a diamond-tipped hammer approximately ten inches through a small glass tube upon a smooth surface of the steel to be tested, and the height of the rebound of the hammer measured against a scale at the back of the glass tube. Hard steel is taken as being 100 hard on the Scleroscope and soft steel approximately 30 to 35 hard. Thus the higher the rebound, the harder the steel. After noting the remarks on the Tensile test, it will be seen readily that the Brinell and Scleroscope tests are excellent methods of check-testing rapidly and accurately, finished and semi-finished parts that it would be impractical to test otherwise. The resulting values obtained by means of the Tensile test are invaluable in both the designing and testing engineers.

The designer must take into consideration the load that the part will be required to carry, the function it must perform, and the nature of the stress to which it will be subjected. The weight of the part must be held to a minimum, and the steel selected must be one capable of withstanding these stresses, at the same time maintaining a wide margin of safety.

A very rigid inspection must be maintained on parts subject to shock and vibration, as tool marks and scratches, under-cut radii, or sharp corners, are frequently the cause of early failures of properly designed and heat-treated parts such as axles, jackshafts, steering knuckles, etc.

Tensile Test

It is a comparatively easy matter to check up on machined parts with gauges and measuring instruments, as the defects and imperfections are generally more or less visible. However, checking up on heat treatments is an entirely different proposition. The Tensile test is the most accurate and most approved method, and is made as follows:

A test bar of the standard S. A. E. form is machined from the material to be tested, and is held in threaded grips in a vertical position in the testing machine. The machine is set in motion and the test bar is slowly stretched until it is broken. The point at which the elongation ceases to be proportional to the load is designated as the elastic limit. This is the highest point at which, if the load were removed, the bar would resume its original length. This is also the point at which, if exceeded, failure of the part commences. The weight of the load at this point is read on the weighing beam of the testing machine and converted into pounds per square inch, to be checked against S. A. E. specifications for that particular steel from which the test bar was made.

The elastic limit point is determined by the use of an extensometer, a delicate instrument which shows the amount the test bar stretches, and is capable of measuring to the ten-thousandth part of an inch. While noting the elastic limit the test continues, and the ultimate tensile strength is noted. This is the greatest load the bar will withstand before it breaks. From this point on to the breaking point, the bar fails rapidly. After breaking, the bar is measured to determine the total elongation and the reduction in area of cross section, and these two values are converted to percent of the original bar dimensions.

Research work is constantly being carried on in the chemical and physical laboratories to produce better materials and better methods of heat treating; and many special tests are devised, such as torsion tests, fatigue tests, impact tests, and vibratory tests. The qualities of designs and their manufacture are frequently proved and checked by tests that approximate as nearly as possible the actual working conditions of the parts.

Fatigue Failures

A fatigue failure of a shaft or axle is characterized by suddenness, lack of warning, apparent brittleness of material, and, in many cases, a fracture with a crystalline appearance over a part of its surface.

This crystalline appearance led to the old theory that under repeated stress steel "crystallized in service," changing from a ductile "fibrous" structure to a brittle "crystalline" one. This theory, however, has been quite thoroughly demolished as a result of study of the structure of steel under the microscope. As revealed by the microscope, all metals have a crystalline structure; the fibrous structure was caused by segregations or inclusions of non-metallic impurities (example: slag in wrought iron). Microscopic examination of steel under stress shows no change of the general scheme of internal structure, but under sufficiently severe stress, there appears a gradual breakdown of the crystals in the structure. This manner of failure is rightly termed a "fatigue failure."

If the fractured surface of a fatigue failure is carefully examined, it is usually seen to be made up of two parts; that is, it appears to have two different-size crystalline structures -- (1) near the extreme outside of the fractured surface it appears dark, dull, and lusterless, with a poorly defined crystalline structure; while the appearance (2) at and immediately surrounding the center of the break is bright and shows a definite crystalline formation. This appearance is caused by the method and nature of the failure, and in that the (1) outside of the fractured surface was caused very slowly and has started from many centers and due to the constant vibration and rubbing together of the two faces of the fracture, the sharp corners of the crystals become worn and smooth; whereas the break at the center and immediately surrounding (2) was suddenly torn in two on the natural surfaces of cleavage with no subsequent vibration or rubbing, thus leaving exposed the original structure of the steel.

Cause of Fatigue Failure

The cause of a fatigue failure may be attributed to a repetition of stresses which exceed the elastic limit of the steel. This may be subdivided as follows:

Manufacturer's Responsibility

1. Defective raw material.
2. Defective heat treatment.
3. Defective design.
4. Defective machining.

Truck Operator's Responsibility

1. Overloading.
2. Overspeeding.
3. Rough handling and driving.
4. Road conditions.

Hardness is that property of a material by virtue of which it resists penetration.

Toughness is that property of a material by virtue of which it resists shock and vibration.

Transmission and differential gears must have hard surfaces and tough cores or centers. They are designed with a 20-degree tooth pressure angle, which causes the teeth to roll together and apart, rather than to slide together and apart from each other, as do gears whose teeth have different angles; thus gear tooth wear is minimized, both by heat treatment and design. Some common causes for gear failures of inferior manufacture are as follows:

1. Lack of hardness, battering and shearing, soft cores.
2. Excessive hardness and attendant brittleness, chipping.
3. Thin "case" and soft core, cracking, and chipping.
4. Case too deep, no tough backing to resist shock.

Extreme care is given the inspection of gears, both as to machined dimensions and heat-treated conditions. Test gears are broken and the structures examined, depth of "case" noted and held to approximately 3/64 - inch deep. They must not batter at corners, and they must not chip. They are hardness-tested by Scleroscope method.

One steel used in making transmission and differential gears is designated by the S.A.E. No. 3120; it is an ideal steel for the manufacture of all parts which are drop-forged and afterwards treated, to develop in them a high degree of strength, and is one of the best carbonizing steels obtainable. Following is the chemical analysis and the physical properties to correspond to a Brinell hardness of 275 or an approximate Shore hardness of 40:

Chemical Analysis

Carbon	0.15 to 0.25%
Nickel	1.00 to 1.50%
Phosphorus	Below 0.04%
Sulphur	Below 0.045%
Chromium	0.45 to 0.75%
Manganese	0.50 to 0.90%

Physical Properties

Elastic limit, lbs. per sq. in.	120,000
Tensile strength, lbs. per sq. in.	160,000
Elongation in 2 in percent	15.00
Reduction of area	52.50
Brinell hardness numeral	275
Shore hardness numeral	40

The chemical analysis and physical properties shown above are those that will be retained by the core or the centers of the gears after carburizing, and are the factors responsible for the toughness and fatigue resistance of the gears. The surfaces are hardened to 75-85 Scleroscope, to an approximate depth of 1/16-inch, this combination of surface hardness and center toughness being the ideal condition and insuring long gear life.

GLOSSARY OF TECHNICAL AND MECHANICAL TERMS

Addendum

That part of a tooth of a gear or of a screw thread between the pitch circle or line and the extreme point of the tooth or thread.

Allowance

Covers variation in dimensions to allow for different qualities of fits.

Alloy Steel

A steel which owes its characteristic properties chiefly to the presence of one or more elements other than carbon; i.e., nickel, chromium, vanadium, molybdenum, etc.

Ampere

The practical unit of electrical current, the current produced by one volt acting through a resistance of one ohm.

Altitude

The perpendicular distance between the bases, or between the vertex and the base of a solid or plane figure.

Angle

The difference in direction of two lines which meet or tend to meet. The lines are called sides, and the point of meeting, the vertex of the angle. They are measured by degrees and by radians. One degree is equivalent to the angle at the center of a circle, subtended by an arc whose length equals one three hundred sixtieth (1/360) of the circumference. One radian is equal to the angle at the center of a circle when subtended by an arc equal in length to the radius of the circle. One radian equals 57.2958 degrees, also 1 radian equals $180/\pi$.

The Protractor is used for the measurement of angles. A right angle is one which is formed by the radius moving through 1/4 of the circumference. It is a square angle and contains 90°.

An acute angle is one containing less than 90°. An obtuse angle is one containing more than 90°.

An oblique angle may be any other than a right angle. A reflex angle is one containing more than 180°.

A helical angle is the angle of a thread at the pitch line, with the axis of a threaded part; the lead angle of a thread is the total or included angle between the sides or walls of a thread, measured on the axial line.

A dihedral angle is one formed by the opening between two intersecting planes.

The vertex of an angle is the point of intersection of the two lines which form the angle.

Annealing

See Heat Treatment.

Austenite

See Metallography.

Bending Moment

A moment is equivalent to the product of a force multiplied by a distance, and is measured in inch-pounds or foot-pounds. The bending moment at any cross section of a piece under flexure measures the tendency to cause flexural failure, and is equal in magnitude to the summation of the moments of the forces on one side of the cross section.

Brinell Test

A hardness-testing instrument, employing the hardened steel ball indentation method.

B.T.U.

Abbreviation for British Thermal Unit which represents the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 37° F. There are 778 foot-pounds of energy in a B.T.U. and 42.4 B.T.U. to one horsepower.

Calibrate

To ascertain the accuracy of and to rectify same, as regards a precision measuring instrument, etc.

Calorie

Any of several thermal units, as: (a) The amount of heat (small calorie) required to raise the temperature of one gram of water one degree Centigrade. (b) The amount of heat (large or great calorie) required to raise a kilogram of water one degree Centigrade. (1 great calorie = 1000 small calories.)

Cantilever

A projecting beam, bar, or member supported at one end only.

Center of Gravity

That point in a body about which all the parts exactly balance each other.

Center of Oscillation

If a body oscillates about a horizontal axis which does not pass through its center of gravity, there will be a point on the line drawn from the center of gravity perpendicular to the axis, the motion of which will be the same as if the whole mass were concentrated at that point. This point is called the center of oscillation.

Center of Percussion

If a body oscillates about an axis then the point at which, if a blow is struck by the body, the percussive action is the same as if the whole mass of the body were concentrated at that point, is called the center of percussion. This point is located at the same point as the center of oscillation.

Center of Gyration

The center of gyration with reference to an axis is the point at which the entire weight of a body may be considered as concentrated, the moment of inertia, meanwhile, remaining unchanged; or, in a revolving body, the center of gyration is the point at which the whole weight of the body may be considered as concentrated, the angular velocity remaining the same.

Centrifugal Force

When a body revolves in a curved path, it exerts a force called the centrifugal force upon the arm or cord which restrains it from moving in a straight (tangential) line.

C or CL

Abbreviation for center line.

C. G. S.

An abbreviation for the Centimeter Gram Second or Absolute System of units much employed in physical science, based upon the centimeter as the unit of length, the gram as the unit of weight, and the second as the unit of time.

Cementite

See Metallography.

Chamfer

A bevel, or a corner or edge removed, a relief.

Coefficient of Friction

The force of friction, F bears -- according to the conditions under which sliding occurs -- a certain relation to the pressure between the bodies; this pressure is called the normal pressure, N. The relation between force of friction and normal pressure is given by the coefficient of friction, generally denoted by the Greek letter μ.

Thus: $F = \mu \times N$, and $\mu = \frac{F}{N}$

Cold Bending

See Cold Working.

Cold-Drawn Steel

See Cold Working.

Cold-Rolled Steel

See Cold Working.

Cold Working

Changing the shape of steel parts by compressing, stretching, bending, or twisting, using stresses beyond the yield point and temperatures below the critical range. Cold-drawn steel is finished by being drawn through a die, while cold-rolled steel is finished between rollers.

Contour

Outline or profile of an object.

Critical Range

See Metallography

Crystal

See Metallography.

Cycle

Applied to the internal-combustion, four-cycle engine, a cycle comprises four strokes for each piston (1, intake; 2, compression; 3, explosion; 4, exhaust) performed during two revolutions of the crankshaft. An interval or period of time occupied by one round or course of events, recurring in the same order in a series.

Decalescence

The sudden absorption of heat observed when metals in process of heating pass certain temperatures.

Dedendum

The dedendum of a gear tooth or of the tooth of a threaded part is the distance from the pitch circle to the root of the tooth or thread.

Deformation

The change of form of a member accompanying the application of external load. The term "strain" is used in this manual as synonymous with deformation. Deformations may be stretches under tension, compressions under compressive loads, deflections under bending (or flexure), twists under torsional moment, or detrusions under shear. Twist is a special case of shearing detrusion. In the physical laboratory the deformation per unit of length over any gauge length on a specimen is called the unit deformation, or unit strain.

Drawing

See Heat Treatment.

Ductility

Ability to withstand stretch without rupture. Ductility is usually measured by the percentage of elongation, after rupture over a gauge length laid off on a specimen before stretching, or by the reduction of area of the original cross section of a specimen when tested in tension.

Dynamic Balance

A crankshaft may be in perfect static balance, but if it is mounted in bearings and revolved at high speed great vibration may develop which would soon cause failure of engine bearings and possibly cause breakage of the shaft itself due to fatigue action.

Dynamic unbalance means that the weight sums of diagonally opposite portions are not equal. Take, for example, a pulley that is in perfect balance. Visualize the pulley mounted on a shaft supported by bearings. Attach a weight to the outer periphery on one edge of the pulley, then attach an exact counterweight to the opposite side of the pulley on the opposite edge. The pulley continues to be in static balance as evidenced by the fact that it turns freely and stops with the counterweights either up, down, or in any other position; but if the pulley is revolved at a high rate of speed its dynamically unbalanced condition will be very much evidenced by the vibration. This dynamic unbalance is eliminated in a crankshaft first by determination of the heavy points and next by drilling into these points until the necessary amount of metal and weight has been removed.

Dyne

The force which acting on one gram for one second imparts to it a velocity of one centimeter per second, or approximately that force exerted by a one milligram weight under the influence of gravitation.

Elastic Limit

The term "elastic limit" is unfortunately used very loosely in general practice. In scientific usage the term is used to denote the highest unit stress at which material will completely recover its form after the stress is removed.

Proportional elastic limit is used to denote the highest unit stress at which stress is proportional to deformation. The values found for both the true elastic limit and the proportional elastic limit are dependent upon the accuracy of the apparatus used, and the precision with which stress strain diagrams are plotted.

For practical purposes elastic limit and proportional limit may be regarded as interchangeable terms.

The yield point is that unit stress at which the material shows a sudden marked increase in the rate of deformation without increase in load. It is usually determined by the sudden drop in the balance beam of the testing machine, as strain is applied to the specimen at a uniform rate or by a sudden increase of deformation which can be seen by the use of a pair of dividers on the specimen.

Elongation

See Ductility.

Endurance

In the physical laboratory this term is used to denote the number of cycles of repeated stress withstood by a specimen before failure.

Endurance Limit

The highest unit stress which, applied in cycles of completely reversed stress, can be withstood an indefinite number of times without failure.

Endurance Strength

A general term denoting ability to resist repeated stress, synonymous with fatigue strength.

Erg

A theoretical unit of work or energy being the work done by one dyne working through a distance of one centimeter.

Extensometer

An instrument for measuring small changes of length of specimens under tension; capable of measuring accurately to one ten-thousandth part of an inch.

Factor of Safety

Working stresses should never exceed the elastic limit. They are generally based on the ultimate strength of the material. The ratio of the ultimate strength of a given material to the allowable working strength is called the "Factor of Safety." The factor of safety may be considered as the product of four primary factors which may be designated as factors a, b, c, and d, designating the factor of safety by **F**.

$$F = a \times b \times c \times d$$

The first of these factors (a) is the ratio of the ultimate strength of the material to the elastic limit, meaning in this case, by the elastic limit, that boundary line within which the material is perfectly elastic and takes no permanent set. For ordinary materials, the factor a = 2; for nickel steel and oil-tempered forgings, it is reduced to 1-1/2.

The second factor (b) depends on the character of the stress within the material. This factor is 1 for a dead load; 2 for a load varying between zero and maximum; and 3 for a load which produces alternately a tension and a compression equal in amount.

The third factor (c) depends upon the manner in which the load is applied to the piece under stress. For a load gradually applied the factor is 2. If the load is applied, not only suddenly but with impact, this factor must be still further increased in value.

The last factor (d) may be called the factor of ignorance, or the "fool factor." The other factors provide against known conditions and this provides against the unknown. It commonly varies in value between 1-1/2 and 3 and occasionally should be given as high a value as 10. It provides against accidental overload, against unexpectedly severe service and unreliable or imperfect materials, etc. When all the conditions are thoroughly known and there is no danger of overload, this factor may be made equal to 1-1/2 for wrought iron and mild steel and 2 for cast iron.

As an example of the use of the formula given for the factor of safety that should be used for an internal-combustion engine connecting rod, the elastic limit will probably be slightly more than one-half the ultimate strength, therefore, a=2. The rod will be alternately in tension and compression, therefore, b=3. The explosional force will be applied suddenly, therefore, c=2. The material is very reliable, therefore, d=1-1/2.

Then F = 2 x 3 x 2 x 1-1/2 = 18.

Fatigue of Metals

The action which takes place in metals causing failure after a large number of applications of stress. Fatigue failures are characterized by their suddenness and by the absence of general deformation in the piece which fails. A wire broken by bending backward and forward is a characteristic fatigue failure.

Ferrite

Pure metallic iron, in the sense here used, entirely free from carbon inclusion.

Fibre Stress or Fiber Stresses

This is the stress in the extreme fiber, or the maximum stress in the cross section considered, due to the application of the load. Fibre stresses with a cantilever would denote tension in the upper fibers and compression in the lower ones, with a neutral plane between.

With a beam supported at both ends, the fiber stress would be the reverse of that in a cantilever. Thus a fibre stress of 50,000 pounds per square inch at point of stress on a cantilever loaded at the free end would denote the maximum stress to which the cantilever was subjected.

Fit

The different classes of fit of shafts in their holes most generally used are as follows:

SHRINK FIT -- For parts which have to be fitted together by means of an application of heat to expand the hole, at which time the shaft is inserted. On cooling the hole contracts, making a perfect union which requires no keys or other anchors of any kind. The bores are always machined to a smaller diameter than that of the shaft.

FORCE FIT -- For parts which have to be fitted together by means of a press; they must be keyed if they are to be subjected to a twisting force.

DRIVING FIT -- For parts which have to be fitted together with a lead hammer, but which can be afterwards disassembled.

PUSH FIT -- For parts which have to be fitted together by hand without special force, and without having perceptible shake when assembled, they should remain motionless in each other.

SLIDING FIT -- For all parts which in functioning have to slide constantly on one another, without turning.

RUNNING FIT -- For parts which in functioning have to revolve constantly one in the other, at a medium speed and with very little play.

EASY RUNNING FIT -- Parts revolving with a relatively large amount of play.

Fillet

A narrow band of material, frequently in shop practice used to designate a radius on a shaft or other part.

Flute

The groove cut in taps and reamers to form the cutting edge and allow room for chips.

Friction

Is the resistance to motion which takes place when one body is moved upon another, and is generally defined as "That force which acts between two bodies at their surface of contact, so as to resist their sliding on each other."

Gauge or Gage

Master, Standard or Reference; terms applying to a nearly perfect gauge used for calibration of working gauges.

Gauge -- Limit

A gauge having two sizes, the difference between them representing the tolerance or allowable variation. One size must go into or over the work being checked, and the other size must not go. These gauges are frequently referred to in shop practice as "tolerance gauges" and as "go" and "no go" gauges.

Gear Tooth Parts

PITCH DIAMETER--PITCH CIRCLE: When one of two gears that are in mesh with each other are revolved, it will drive the other gear at a certain rate of speed. Imagine that, as well as the two gears, two discs without teeth are also in contact, so that when one disc is revolved it will drive the other disc by frictional force. The diameters of the discs may be so selected that when one revolves at the same rate as the gear to which it corresponds, it will drive the other disc at the same rate as the second gear is driven. The diameters of the discs are then the same as the pitch diameters of the gears, and the circumferences of these discs represent the pitch circles of the gears.

The outside diameter of a gear is the diameter measured over the top of the teeth.

The root diameter of a gear is the diameter measured at the bottom or roots of the teeth.

The center distance is the distance between the centers of two meshing gears, the pitch circles of which are tangent to each other.

The diametral pitch of a gear is the number of teeth for each inch of pitch diameter, and is found by dividing the number of teeth by the pitch diameter.

Bastard gear teeth are sometimes generated for special purposes, having their teeth of different pitches with regards to width and depth. Example, a gear of 6/8 pitch the teeth correspond in width or thickness to 6 pitch, and in depth tq 8 pitch.

The circular pitch is the distance from the center of one tooth to the center of the next, measured as an arc along the pitch circle.

The chordal pitch is the distance (on the pitch line) from the center of one tooth to the center of the next, measured along a straight line.

The thickness of a gear tooth is generally understood to be the thickness at the pitch circle, measured along the circular arc.

The chordal thickness of a tooth is the thickness at the pitch circle measured along a straight line or as a chord.

The addendum of a gear tooth is the distance from the pitch circle to the top of the tooth.

The dedendum of a gear tooth is the distance from the pitch circle to the root of the tooth.

The working depth is the depth to which the teeth in a meshing gear enter into the spaces between the teeth of the opposing gear.

The clearance is the amount by which the tooth space is cut deeper than the working depth.

The face of the tooth is that part of the tooth curve that is between the outside circumference and the pitch circle.

The flank of the tooth is that part of the working depth of the tooth which comes inside of the pitch circle.

Gravity

The attraction of bodies toward the center of the earth. Under the influence of gravity alone, all bodies fall to the earth with the same velocity and with the same acceleration. The acceleration increases with the latitude and decreases with the elevation above the level of the sea. Its value at the level of the sea in the latitude of New York is 32.16 feet per second. (In the metric system, Gravity = 9.81 meters per second at 45 degrees latitude and sea level.)

Grain

See Metallography.

Hardness

Is that property of a material by virtue of which it resists penetration. The two common tests for hardness are the Brinell test and the Scleroscope test. In the Brinell test a hardened steel ball of a standard diameter is forced against the surface of a test specimen, using a standard pressure. The diameter or the depth of the resulting impression is an inverse measure of the hardness. In the Scleroscope test a small weight fitted with a diamond point is allowed to fall from a standard height upon the surface of the specimen, thus causing a minute indentation. The height of rebound is a measure of the hardness.

Heat-Treatment

HEAT-TREATMENT of steel is the proper control of heating and cooling so as to produce the desired struction, pearlite, sorbite, troostite, martensite, or austenite, and includes:

ANNEALING, which consists of a very slow cooling from above the critical range and which gives a large-grained, soft pearlitic structure.

NORMALIZING, which consists in cooling from above critical range in still air and which gives a fine-grained, pearlitic structure.

OIL-QUENCHING, which consists in cooling from above the critical range by cooling in oil at room temperature and which yields steel of sorbitic or troostitic structures, depending on the carbon content (certain special alloy steels yield a martensitic structure or even an austenitic structure with oil-quenching).

WATER-QUENCHING, which consists in cooling from above the critical range by cooling in water at room temperature and which yields steel of martensitic, troostitic or sorbitic structure, depending on the carbon content (certain special alloy steels yield a martensitic or austenitic structure with water-quenching).

DRAWING, which consists in reheating quenched steel to a temperature slightly below the critical range and cooling. This process tends to bring martensitic, troostitic or sorbitic steel towards the pearlitic state, and, by varying the temperature of drawing both thermally and as to time, it is possible to control the state of the steel with an excellent degree of precision.

Other liquids are sometimes used for quenching steel: such as molten lead, molten barium chloride, ice water, mercury, and brine.

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Alloying elements, including carbon, slow up the transition period so that high-carbon steels and alloy steels are more susceptible to heat treatment than are low-carbon steels.

See Metallography.

Helix

A spiral. A coiled spring or a screw thread forms a helix.

High-Precision Work

This term generally applies to the manufacture of measuring instruments, magnetos, special machine tools, electrical instruments, automotive practice, etc., and generally for all kinds of apparatus for which the fits must be made with extreme accuracy and in which accordingly the interchangeability of the various parts must be uniform to a high degree.

Horsepower

See Mechanics.

Hydraulics

The science dealing with liquids in motion.

Hydrostatics

The science of the pressure and equilibrium of liquids (incompressible fluids).

Hyper-Eutectic Steel

Steel more highly carburized than eutectoid steel is called hyper-eutectoid, or hyper-eutectic steel, and therefore contains free cementite, i.e., high-carbon steel.

Hypo-Eutectic or Eutectoid

Steel containing less than 0.85 to 0.90% Carbon and therefore some free ferrite is called hypo-eutectoid or hypo-eutectic steel, i.e., low-carbon steel.

Hypoid

Hypoid (contraction of the word hyperboloid) meaning that the pinion is offset with respect to the center line of the ring gear.

Hysteresis -- Mechanical

If a load is applied to a specimen, and is removed, then, if the specimen is perfectly elastic under the stress caused by the load, the energy expended in loading the specimen is all given back when the load is removed. If the specimen is not perfectly elastic under the stress caused by the load, then some of the energy applied is dissipated as heat. This dissipated energy is called "mechanical hysteresis."

Inch-Pounds

A term used to denote work or energy.

Inertia

See Mechanics.

Iron

See steel for distinction between iron and steel.

Joule

A unit of work or energy, approximately equal to .738 foot-pounds or .24 small calorie, or approximately the energy expended in one second by an electric current of one ampere in a resistance of one ohm, is a joule.

Land

One of the sharpened ridges which make up the cutting section of a tap, die, reamer or milling cutter after the flutes or chip clearance spaces have been removed.

Lead

The longitudinal distance which a screw thread advances when turned one complete revolution.

Limit

A maximum or minimum dimension slightly above or below a standard size, not the distance between dimensions. See Tolerance.

Martensite-Martensitic

See Heat-Treatment; also Metallography.

Mechanics

Is the science of applied mathematics which treats of the action and effect of forces on bodies.

A force is defined as any cause tending to produce or modify motion. The units by which a force is usually measured are pounds or tons.

Besides force there are two other elementary quantities in mechanics from which numerous compound quantities are derived. These are distance, measured in linear units as inches, feet, etc., and time, expressed in hours, minutes, or seconds.

WORK, in mechanics, is the product of force by distance, and is expressed by a combination of units of weight (force), and distance, as inch-pounds, foot-pounds, foot-tons, etc.

POWER, in mechanics, is the product of force by distance, divided by time, or the performance of a given amount of work in a given time and is expressed as inch-pounds per minute, foot-pounds per minute or second, etc. The term "power" is frequently used by writers or mechanics to designate a force. In connection with the so-called "mechanical power" -- the lever, wheel and axle, wedge, screw, etc. -- it is usual to speak of the applied force as the power; this is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given above.

HORSEPOWER (abbreviated H.P.) is the unit of power adopted for engineering work. One horsepower is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second. The metric horsepower is equal to 75 kilogram-meters per second, or 542.5 foot-pounds per second, or 32,550 foot-pounds per minute. The kilowatt used in electrical work equals 1.34 horsepower; or one horsepower equals 0.746 kilowatt.

VELOCITY is distance divided by time, and is expressed in feet per minute, miles per hour, etc.

INERTIA is that property of a body which causes it to tend to continue in its present state of rest or motion, unless acted upon by some force.

Metallography

Deals with the physical state and the proximate constituents of a metal or an alloy. It has to do with the physical grouping, distribution of constituents and relative dimensions, of the substances as revealed by microscopic examination. It may be characterized as a study of the anatomy of metals.

Steel is an alloy, the essential constituents of which are iron and carbon, the latter being the controlling element. The carbon exists in steel as a carbide of iron, Fe_3C, to which the name cementite is applied. The free iron or ferrite, together with the cementite, has the power of forming a conglomerate called pearlite, a very intimate mechanical mixture composed of about 7 parts of ferrite to one part of cementite.

If molten iron is cooled there is formed first a solution of carbon in molten iron; then, as the metal solidifies, the carbon exists as cementite in solid solution in the iron. This solid solution is called austenite, and it crystallizes into imperfect crystals or grains.

With further cooling the steel passes through a critical or transformation range of temperature (extreme range about 1650° F. to 1250° F.) and the two constituents of the metal pass successively through several transition stages, namely: martensite, in which long needle-like crystals are formed, giving a very hard and brittle substance; troostite, in which dark-colored masses resembling sorbite are surrounded by a groundwork of martensite, the troostitic state yielding a substance hard but tougher than the martensite; sorbite, in which cementite and ferrite are in a state resembling an emulsion, yielding a substance fairly hard and very tough; and pearlite, in which bands of ferrite and cementite exist, usually in stratified layers or bands.

If the steel has a carbon content of about 0.90%, all the grains will be pearlite; if the carbon content is lower than 0.90% there will be grains of pearlite and grains of ferrite; if the carbon content is greater than about 0.90% there will be grains of pearlite and grains of cementite.

The presence of carbon or of other alloying elements slows down the process of transition. By varying the rate of quenching steel, the transition process may in general be halted at any desired state, and the resulting cooled steel may be given any desired characteristic structure. See Heat-Treatment, also Micrograph.

Micrographs

Are obtained by polishing the surface of a metal, etching the polished surface with a suitable reagent to bring out the metallographic structure, then reproducing, usually by photographic methods, the appearance of the surface as seen through the microscope. Photomicrograph and microphotograph are terms sometimes used for micrographs made by a photographic process.

Mil, Circular

A circular mil is the area of a circle 0.001 inch in diameter and is a unit in the measurement of diameters and cross-sectional areas of electric wires.

Millivoltmeter

An electrical instrument for measuring small electric potentials. Used for measuring the small voltages of thermo-couples developed by changes of temperature. (See Pyrometer.)

Modulus of Elasticity

Is the quotient obtained by dividing the stress per square inch by the elongation in one inch caused by this stress. For all stresses below the elastic limit, the unit stress bears a constant ratio to the unit deformation.

Moment of a Force

The moment of a force with respect to a point is the product of the force multiplied by the perpendicular distance from the given point to the direction of the force. The perpendicular distance is called the lever arm of the force.

The moment is the measure of the tendency of the force to produce rotation about the given point, which is termed the center of moments. Moments are expressed in inch-pounds, foot-pounds, etc., and are designated as clockwise or contraclockwise, according to their direction. The term torque is equivalent to the term moment.

Moment of Inertia

The moment of inertia of a body with respect to an axis is the sum of the products obtained by multiplying the weights of each elementary particle by the square of its distance from the axis. Therefore, the moment of inertia of the same body varies according to the position of the axis. It has its minimum value when the axis passes through the center of gravity. The moment of inertia is numerically equal to the weight of the body which if it could be conceived of as concentrated at a distance of unity from the axis of rotation, would, if actuated by the same forces, rotate with the same angular velocity as that of the actual body. In other words, the moment of inertia bears the same relation to angular acceleration as weight does to linear acceleration. When the term "moment of inertia" is used in regard to areas, it is equal to the sum of the products obtained by multiplying each elementary area by the square of its distance from the axis. The moments of inertia of surfaces are especially useful in calculating the strength of beams.

Momentum

The momentum of a moving body is the intensity of that constant force which, resisting its movement, would bring it to rest in one second.

Momentum = mass X velocity in feet per second.

$$\text{Momentum} = \frac{\text{weight}}{32.16} \times \text{velocity in feet per second.}$$

Momentum should not be confused with the moment of a force, defined above.

Motion, Newton's Three Laws

1ST LAW: Every body continues in a state of rest of uniform motion in a straight line, except if it is acted upon by a force to change its state of motion or rest.

2ND LAW: If a body is acted upon by several forces, it is acted upon by each of these as if the others did not exist. This is true whether the body is at rest or in motion. In other words, if two or more forces act upon a body at the same time, each produces exactly the same effect as if it acted alone; the total effect or resultant motion of all the forces may be found by a diagram in the same way as the resultant of forces is found.

3RD LAW: To every action there is always an equal reaction or, in other words, if a force acts to change the state of motion of a body, the body offers a resistance equal and directly opposite to the force.

Neutral Plane

See Fibre Stress.

Nonferrous Metals

Metals in which iron is not a constituent.

Ohm

The practical unit of electrical resistance, being the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

Pearlite

See Metallography.

Physics

The science of phenomena of inanimate matter involving no chemical changes, comprising mechanics, magnetism, electricity, light, heat, and sound.

Pi-π

The 16th letter of the Greek Alphabet, corresponding to the English P, is used as a constant to denote the ratio (3.14159+) of the circumference of a circle to its diameter.

Pitch, Diametral, Circular

See Gear Tooth Parts

Pitch Diameter

See Gear Tooth Parts.

Pneumatics

That branch of physics treating of the mechanical properties of air and other gases, as of their weight, pressure, elasticity, etc.

Pound-Inches-Feet

See Moments of a Force; Mechanics, etc.

Power

See Mechanics.

Prony Brake

See Horsepower.

Pyrometer

An instrument for measuring high temperatures. Briefly, one type of pyrometer (that in use by International Harvester) is of the Thermo-electric type, which utilizes the electromotive force generated by a junction of two dissimilar metals when exposed to heat. In each pyrometer there are two junctions made by welding together wires of two dissimilar metals, platinum and platinum-rhodium; for example, one junction is then exposed to the temperature to be measured and is called the "hot junction"; the other junction, which is opposed to the first named junction, is kept at a constant temperature and is called the "cold junction." A mill voltmeter for measuring electromotive force is attached by conductors to the free ends of the opposed junctions and by its reading indicates the electromotive force generated and hence the temperature of the "hot junction."

Recalescence

The sudden unproportional liberation of heat by steel when cooling through its critical range.

Scleroscope

See Hardness.

Shear

Shearing Stress; See Stress.

Sorbite

See Metallography.

Static Balance

Balancing of crankshafts is a very important factor in providing long engine life. Crankshafts must be balanced for equalization of weight so that when supported on knife blades the shaft will not revolve. This is the same condition of balance that would obtain with an automobile wheel if a slight counterweight were placed directly opposite the valve stem so that the wheel if jacked up and given a spin would stop and remain stationary wherever it was overtaken by inertia after the energy from the force of the spin had spent itself. If not in perfect balance the wheel would either turn over another revolution or turn back until the heavy point was down.

Elimination of the heavy place on a crankshaft is termed static balancing. This is accomplished by grinding off portions of the balancing pads forged into both sides of each throw for that purpose.

Static Test

A test of a specimen in which the rate of application of load is so slow that it may be regarded as zero. The term refers in general to a test made with an ordinary Tensile Testing Machine.

Steel

The term "steel" is used to denote any ferrous metal with a carbon content less than about 1.7%, which is made by a process involving complete fusion. Wrought iron has a low carbon content, and is made from a pasty mass at a temperature below complete fusion. Ferrous metals with carbon content higher than about 1.7% are called "cast iron."

Stress

An internal force which resists the destructive action of external force. Stresses are always accompanied by strains and deformations. There are tensile stresses, compressive stresses, and shearing stresses. At any point on a stressed member the stress per unit area is called the "unit stress." See "Deformation." Stress is the force applied, and:

Strain

Is the resulting deformation.

Specific Gravity

Is a number indicating how many times a certain volume of material is heavier than an equal volume of water at a temperature of 62° F. The weight of one cubic inch of pure water at 62° F. is 0.0361 pound. If the specific gravity of any material is known, the weight of a cubic inch of the material can, therefore, be determined by multiplying its specific gravity by 0.0361.

Tensile Strength

See Ultimate Tensile Strength.

Tolerance

The range of distance between specified limits, as applied to machine shop practice.

Torsion

That force with which a twisted part tends to return to a state of rest.

Torque

Torque is that which produces or tends to produce rotation or torsion; the product of tangential force multiplied by the radius of the part it rotates. An engine is therefore essentially a device for producing torque, and torque is the energy available for producing work. See also "Moment of Force."

Toughness

Denotes a combination of strength and ductility, resistance to fatigue, tension, and shear.

Troostite

See Metallography.

Ultimate Tensile Strength

The highest unit stress carried by a tension specimen in a test to rupture.

Velocity

See Mechanics.

Volt

The unit of electromotive force; that electromotive force which, if steadily applied to a conductor having a resistance of one ohm, will produce a current of one ampere. It is practically equal to 10^{0} C.G.S. Electromagnetic units.

Watt

A unit of electrical power or activity equal to 10^7 C.G.S. units of power (Ergs, see "Erg") or to the rate of work represented by a current of one ampere under a pressure of one volt, a volt-ampere. One horsepower is approximately equal to 746 watts.

Work

See Mechanics.

Wrought Iron

See Steel.

WEIGHTS, MEASURES, EQUIVALENTS

STANDARD WEIGHTS AND MEASURES

LONG MEASURE

12 In.	1 Ft.
3 Ft.	1 Yd.
16-1/2 Ft.	1 Rod
320 Rods	1 Mile
1,760 Yds. or 5,280 Ft.	1 Mile

SQUARE MEASURE

144 Sq. In.	1 Sq. Ft.
9 Sq. Ft.	1 Sq. Yd.
4,840 Sq. Yds., 43,560 Sq. Ft.	1 Acre
640 Acres	1 Sq. Mile

An Acre=A square whose side is 208.71 Ft. long.

SOLID OR CUBIC MEASURE

1,728 Cu. In.	1 Cu. Ft.
27 Cu. Ft.	1 Cu. Yd.

1 Cord Wood = A pile 4 Ft. wide x 4 Ft. high x 8 Ft. long = 128 Cu. Ft.

LIQUID MEASURE

4 Gills	1 Pt.
2 Pts.	1 Qt.
4 Qts.	1 Gal.

The U.S. Gallon = 231 Cu. In. = .13373 Cu. Ft.
The English Gallon = 277.274 Cu. In.
The English Gallon = 1.20032 U.S. Gallons=The volume of 10 lbs. of water at 62° F.

U. S. DRY MEASURE

2 Pts.	1 Qt.
8 Qts.	1 Pk.
4 Pks.	1 Bu.
1 Bu.	2150.42 Cu. In. = 1.2445 Cu. Ft.

A heaped bushel equals 1-1/4 struck bushels as measured above.

COMMERCIAL MEASURE OF WEIGHT

Avoirdupois or Commercial Weight

437.5 Grains	1 Oz.
16 Oz. or 7000 Grains	1 Lb.
2,000 Lbs.	1 Net or Short Ton (Commonly Used)
2,240 Lbs.	1 Gross or Long Ton

BOARD MEASURE

The unit of solid measure for boards is the foot board measure (B.M.). This is a volume 1 in. in thickness, 12 in. in width, and 1 ft. in length. To obtain the number of feet B.M. of a board or piece of square timber, multiply the length in feet and the breadth in feet and the thickness in inches.

WEIGHT AND MEASURE EQUIVALENTS

1,728 cu. in.	1 cu. ft.	27 cu. ft.	1 cu. yd.
46,656 cu. in.	1 cu. yd.	128 cu. ft.	1 cord
2,150 cu. in.	1 bushel	1.24 cu. ft.	1 bushel
7,056 cu. in.	1 barrel	4.08 cu. ft.	1 barrel
231 cu. in.	1 gallon	20.75 cu. ft.	1 hay bale
144 cu. in.	1 bd.-ft.	10.75 cu. ft.	1 sm. bale
		20-23 cu. ft.	1 cotton bale

SIZE OF BARRELS AND BASKETS
U. S. STANDARD BUSHEL

1 Bushel	4 Pecks	2445 cu. ft.	2150.42 cu. in.
1 Peck	8 Quarts	.3111 cu. ft.	537.61 cu. in.
1 Quart	2 Pints	.0389 cu. ft.	67.20 cu. in.

U.S. STANDARD BARRELS FOR VEGETABLES, FRUIT AND DRY COMMODITIES, EXCEPT CRANBERRIES

1. Capacity . . . . 7,056 cu. in.
105 dry qts.
3.28 bu.
Head diam. . . . . 17.125 in.
Bilge diam. . . . . 20.37 in.
Stave lgth. . . . . 27.125 in.

2. Capacity . . . . 5,826 cu. in.
87 dry qts.
2.709 bu.
Head diam. . . . . 16.25 in.
Bilge diam . . . . 18.62 in.
Stave lgth. . . . . 28.5 in.

3. **Flour Barrel**
Weight . . . . 200 to 220 lbs.
Head diam. . . . . 18 in.
Bilge diam. . . . . 21 in.
Stave lgth. . . . . 28.5 in.

4. **Sugar Barrel**
Weight . . . . 300 to 360 lbs.
Head diam. . . . . 20.5 in.
Bilge diam . . . . 25.0 in.
Stave lgth . . . . 30.0 in.

5. **Syracuse Salt Barrel**
Weight . . . . 280 lbs.
Head diam. . . . . 18 in.
Bilge diam. . . . . 21 in.
Stave lgth. . . . . 29 in.

ABBREVIATIONS FOR TERMS OF WEIGHT AND MEASURE

Following the name of each unit in the list below is given the abbreviation which the Bureau has adopted. Attention is particularly called to the following principles:

1. The period is omitted after the abbreviations of the metric units, while it is used after those of the customary system.

2. The exponents "2" and "3" are used to signify area and volume, respectively, in the case of the metric units instead of the longer prefixes "sq." or "cu." In conformity with this principle the abbreviation for cubic centimeter is "cm^3" instead of "c.c." or "c.m." The term "cubic centimeter" as used in chemical work is, in fact, a misnomer, since the unit actually used is the "milliliter," which has a slightly larger volume.

3. The use of the same abbreviation for both singular and plural is recommended. This practice is already established in expressing metric units and is in accordance with the spirit and chief purpose of abbreviations.

4. It is also suggested that, unless all the text is printed in capital letters, only small letters be used for abbreviations except in the case of A, for acre, where the use of the capital letter is general.

Unit	Abbreviation
acre	A
area	a
avoirdupois	av.
barrel	bbl.
board foot	bd. ft.
bushel	bu.
carat, metric	c
centare	ca
centigram	cg
centiliter	cl
centimeter	cm
chain	ch.
cubic centimeter	cm^3
cubic decimeter	dm^3
cubic dekameter	dkm^3
cubic foot	cu. ft.
cubic hectometer	hm^3
cubic inch	cu. in.
cubic kilometer	km^3
cubic meter	m^3
cubic mile	cu. mi.
cubic millimeter	mm^3
cubic yard	cu. yd.
decigram	dg.
deciliter	dl
decimeter	dm
decistere	ds
dekagram	dkg
dekaliter	dkl.
dekameter	dkm.
dekastere	dks
dram or drachm, apothecaries'	dr. ap. or Z
dram, avoirdupois	dr. av.
dram, fluid	fl. dr.
fathom	fath.
foot	ft.
firkin	fir.
furlong	fur.
gallon	gal.
grain	gr.
gram	g.
hectare	ha
hectogram	hg
hectoliter	hl
hectometer	hm
hogshead	hhd.
hundredweight	cwt.
inch	in.
kilogram	kg
kiloliter	kl
kilometer	km
link	li.
liquid	liq.
liter	l
meter	m
metric ton	t
micron	u
mile	mi.
milligram	mg.
milliliter	ml
millimeter	mm
millimicron	mu

Unit	Abbreviation
minim	min. or mu
ounce	oz.
ounce, apothecaries'	oz. ap. or Z
ounce, avoirdupois	oz. av.
ounce, fluid	fl. oz.
ounce, troy	oz. t.
peck	pk.
pennyweight	dwt.
point	pt.
pound	lb.
pound, apothecaries'	lb. ap.
pound, avoirdupois	lb. av.
pound, troy	lb. t.
quart	qt.
rod	rd.
scrupe, apothecaries	s. ap. or Z
square centimeter	cm^2

Unit	Abbreviation
square chain	sq. ch.
square decimeter	dm^2
square dekameter	dkm^2
square foot	sq. ft.
square hectometer	hm^2
square inch	sq. in.
square kilometer	km^2
square meter	m^2
square mile	sq. mi.
square millimeter	mm^2
square rod	sq. rd.
square yard	sq. yd.
stere	s.
ton	tn.
ton, metric	t
troy	t.
yard	yd.

UNITS OF WEIGHT AND MEASURE

(From Circular No. 47 of Bureau of Standards, Department of Commerce, Washington, D.C.)

THE METRIC SYSTEM: Metric units are naturally related. For example: 1 cubic decimeter equals, for all practical purposes, 1 liter, and 1 liter of water weighs 1 kilogram. The metric terms are formed by combining the words "meter," "gram" and "liter" with the six numerical prefixes, as in the following table:

Prefixes	Meaning		Units
milli- = one-thousandth	$\frac{1}{1000}$	.001	"meter" for length
centi = one-hundredth	$\frac{1}{100}$	.01	
deci- = one-tenth	$\frac{1}{10}$	.1	"gram" for weight or mass
Unit = one	$\frac{10}{1}$	1	
deka- = ten		10	
hecto- = one hundred	$\frac{100}{1}$	100	"liter" for capacity
kilo- = one thousand	$\frac{1000}{1}$	1000	

Definitions of Units

The following lists of units include most of those in general use. Simple conversions may be made from the values here given. For example, if a conversion into nautical miles is wanted, the conversion factor for statute mile given in the conversion tables may be used by multiplying it by the factor 1.151553 here given to show relation of nautical mile to statute mile.

Length

FUNDAMENTAL UNITS

A meter (m) is a unit of length equivalent to the distance between the defining lines on the international prototype meter at the International Bureau of Weights and Measures when this standard is at the temperature of melting ice (0°C.).

1 m. = $\frac{3937}{3600}$ yd.

A yard (yd.) is a unit of length equivalent to $\frac{3600}{3937}$ of a meter.

HIGHER AND LOWER UNITS

1 kilometer (km) = 1000 meters.
1 hectometer (hm) = 100 meters.
1 dekameter (dkm) = 10 meters.
1 decimeter (dm) = 0.1 meter.
1 centimeter (cm) = 0.01 meter.
1 millimeter (mm) = 0.001 meter = 0.1 centimeter.
1 micron (u) = 0.000 001 meter = 0.001 millimeter.
1 millimicron (mu) = 0.000 000 001 meter = 0.001 micron.

1 foot (ft.) = $\frac{1}{3}$ yard = $\frac{1200}{3937}$ meter.

1 inch (in.) = $\frac{1}{36}$ yard = $\frac{1}{12}$ foot = $\frac{100}{3937}$ meter.

1 link (li) = 0.22 yard = 7.92 inches.
1 rod (rd.) = 5-1/2 yards = 16-1/2 feet.
1 chain (ch.) = 22 yds. = 100 links = 66 feet = 4 rods.
1 furlong (fur.) = 220 yards = 40 rods = 10 chains.
1 statute mile (mi.) = 1760 yards = 5280 feet = 320 rods.
1 hand = 4 inches.

1 point = $\frac{1}{72}$ inch.

1 mil = 0.001 inch.
1 fathom = 6 feet.
1 span = 9 inches = 1/8 fathom.
1 nautical mile
1 seal mile
1 geographical mile
} United States=6080.20 feet=1.151 553 statute miles=1353.249 meters

Area

FUNDAMENTAL UNITS

A square meter (m^2) = 1.195985 sq. yd.
A square yard (sq. yd.) = 0.8361307 m^2.

HIGHER AND LOWER UNITS

1 square kilometer (km^2) = 1 000 000 square meters.
1 hectare (ha) or square hectometer (hm^2) = 10 000 square meters.
1 area (a), or square dekameter (dkm^2) = 100 square meters.
1 centare (ca) = 1 square meter.
1 square decimeter (dm^2) = 0.01 square meter.
1 square centimeter (cm^2) = 0.0001 square meter.
1 square millimeter (mm^2) = 0.000 001 square meter = 0.01 square centimeter.

1 square foot (sq. ft.) = $\frac{1}{9}$ square yard.

1 square inch (sq. in.) = $\frac{1}{1296}$ square yard = $\frac{1}{144}$ square foot.

1 square link (sq. li.) = 0.0484 square yard = 62.7264 square inches.
1 square rod (sq. rd.) = 30.25 square yards = 272.25 square feet = 625 square links.
1 square chain (sq. ch.) = 484 square yards = 16 square rods = 100 000 square links.
1 acre (A) = 4840 square yards = 160 square rods = 10 square chains.
1 square mile (sq. mi.) = 3 097 600 square yards = 640 acres.

Volume

FUNDAMENTAL UNITS

A cubic meter (m^3) = 1.307 9428 cu. yd.
A cubic yard (cu. yd.) = .017645594 m.

HIGHER AND LOWER UNITS

1 cubic kilometer (km^3) = 1 000 000 000 cubic meters.
1 cubic hectometer (hm^3) = 1 000 000 cubic meters.
1 cubic dekameter (dkm^3) = 1000 cubic meters.
1 stere (s) = cubic meter.
1 cubic decimeter (dm^3) = 0.001 cubic meter.
1 cubic centimeter (cm^3) = 0.000 001 cubic meter = 0.001 cubic decimeter.
1 cubic millimeter (mm^3) = 0.000 000 001 cubic meter = 0.001 cubic centimeter.

1 cubic foot (cu. ft.) = $\frac{1}{27}$ cubic yard.

1 cubic inch (cu. in.) = $\frac{1}{46656}$ cubic yard = $\frac{1}{1728}$ cubic foot.

1 board foot = 144 cubic inches = $\frac{1}{12}$ cubic foot.

1 cord (cd.) = 128 cubic feet.

Capacity

FUNDAMENTAL UNITS

A liter (1) is a unit of capacity equivalent to the volume occupied by the mass of 1 kilogram of pure water at its maximum density (at a temperature of 4° C. practically and under the standard atmospheric pressure of 760 mm). It is equivalent in volume to 1.00 027 cubic decimeters. One liter = 0.264168 gal.

A gallon (gal.) is a unit of capacity equivalent to the volume of 231 cubic inches. It is used for the measurement of liquid commodities only. 1 gal. = 3.785 332 liter. A British gallon is approximately 20 percent larger.

A bushel (bu.) is a unit of capacity equivalent to the volume of 2150.42 cubic inches. It is used in the measurement of dry commodities only. The bushel is the so-called stricken or struck bushel. Many dry commodities are sold by heaped bushel, which is generally specified in the State Laws to be the usual stricken bushel measure "duly heaped in the form of a cone as high as the article will admit" or "heaped as high as may be without special effort or design." The heaped bushel was originally intended to be 25 percent greater than the bushel. A British bushel is 3 percent larger.

HIGHER AND LOWER UNITS

1 hectoliter (hl) = 100 liters.
1 dekaliter (dkl) = 10 liters.
1 deciliter (dl) = 0.1 liter.
1 centiliter (cl) = 0.01 liter.
1 milliliter (ml) = 0.001 liter = 1.000 027 cubic centimeters.
1 liquid quart (liq. qt.) = 1/4 gallon = 57.75 cubic inches.
1 liquid pint (liq. pt.) = 1/8 gallon = 1/2 liquid quart = 28.875 cubic inches.
1 gill (gi.) = 1/32 gallon = 1/4 liquid pint = 7.21875 cubic inches.
1 fluid ounce (fl. oz.) = $\frac{1}{128}$ gallon = 1/16 liquid pint.
1 fluid dram (fl. dr.) = 1/8 fluid ounce = $\frac{1}{128}$ liquid pint.
1 minim (min.) = $\frac{1}{60}$ fluid dram = 1/4 80 fluid ounce.
1 firkin (fir.) = 9 gallons.

1 peck (pk.) = 1/4 bushel = 537.605 cubic inches.
1 dry quart (dry qt.) = 1/32 bushel = 1/8 peck = 67.200 625 cubic inches.
1 dry pint (dry pt.) = 1/64 bushel = 1/2 dry quart= 33.600 312 5 cubic inches.
1 barrel (bbl.) (for fruit, vegetables and other dry commodities) = 7056 cubic inches = 105 dry quarts (By U.S. Statute, March 4, 1915).

Mass or Weight

FUNDAMENTAL UNITS

A kilogram (kg) is a unit of mass equivalent to the mass of the International prototype kilogram at the International Bureau of Weights and Measures. One kg. = 2.204 622 341 lb. av.

An avoirdupois pound (lb. av.) = 0.453 592 427 7 kilogram. A gram (g) is a unit of mass equivalent to one-thousandth of the mass of the International prototype kilogram at the International Bureau of Weights and Measures.

A troy pound (lb. 61) is a unit of mass equivalent to 5760/7000 of that of the avoirdupois pound.

HIGHER AND LOWER UNITS

1 metric ton (t) = 1000 kilograms.
1 hectogram (hg) = 100 grams = 0.1 kilogram.
1 dekagram (dkg) = 10 grams = 0.01 kilogram.
1 decigram (dg) = 0.1 gram.
1 centigram (cg) = 0.01 gram.
1 milligram (mg) = 0.001 gram.
1 avoirdupois ounce (oz. av.) = $\frac{1}{6}$ avoirdupois pound.
1 avoirdupois dram (dr. av.) = 1/2 56 avoirdupois pound = 1/16 avoirdupois ounce.
1 grain (gr.) = $\frac{1}{7000}$ avoirdupois pound = $\frac{10}{4375}$ avoirdupois ounce = $\frac{1}{5760}$ troy pound.

1 apothecaries' pound (lb. ap.) = 1 troy pound = $\frac{5760}{7000}$ avoirdupois pound.
1 apothecaries' or troy ounce (oz. ap. or z, or oz. t.) = $\frac{1}{12}$ troy pound = $\frac{480}{7000}$ avoirdupois pound = 480 grains.
1 apothecaries' dram (dr. ap or Z) = $\frac{1}{96}$ apothecaries' pound = 1/8 apothecaries' ounce = 60 grains.
1 pennyweight (dwt.) = $\frac{1}{20}$ troy ounce = 24 grains.
1 apothecaries' scruple (s. ap. or S) = $\frac{1}{3}$ apothecaries' dram = 20 grains.
1 metric carat (c) = 200 milligrams = 0.2 gram.
The old carat in use in this country previous to July 1, 1913, was of 205.3 milligrams.
1 short hundredweight (sh. cwt.) = 100 avoirdupois pounds.
1 long hundredweight (1 cwt.) = 112 avoirdupois pounds.
1 short ton (sh. tn.) = 2000 avoirdupois pounds.
1 long ton (1. tn.) = 2240 avoirdupois pounds.

FRENCH AND AMERICAN EQUIVALENT MEASUREMENTS

Measures of Length

FRENCH			AMERICAN
1	meter	39.37	inches, or 3.28083 feet
.3048	meter	1	foot
1	centimeter	.3937	inch
2.54	centimeters	1	inch
1	millimeter	.03937	inch, or $\frac{1}{22}$ inch nearly
25.4	millimeters	1	inch
1	kilometer	1093.61	yards, or .62137 mile

EQUIVALENT VALUES OF ELECTRICAL, MECHANICAL AND HEAT UNITS

Units	Equivalent Value in Other Units	
1 Kilowatt Hour=	1,000	watt hours
	1.341	horsepower hours
	2,655,180	ft.-lbs.
	3,600,000	joules
	3,415	heat units
	367,100	kilogram meters
	0.234	lb. carbon oxidized with perfect efficiency
	3.52	lbs. water evaporated from and at 212 degrees F.
	22.77	lbs. water raised from 62 degrees to 212 degrees F.
1 Horsepower Hour =	0.7457	kilowatt hour
	1,980,000	ft.-lb.
	2,546.5	heat units per hour
	273,740	kilogram meters
	0.174	lb. carbon oxidized with perfect efficiency
	2.62	lb. water evaporated from and at 212 degrees F.
	17.0	lb. water raised from 62 degrees to 212 degrees F.

Unit	Equivalent Value in Other Units	
1 Kilowatt =	1,000	watts
	1.3410	horsepower
	2,655,180	ft.-lbs. per hour
	44,253	ft.-lbs. per minute
	737.56	ft.-lbs. per second
	3,415	heat units per hour
	56.92	heat units per minute
	0.9846	heat units per second
	0.234	lb. carbon oxidized per hour
	3.52	lbs. water evap. per hour from and at 212 degrees F.
1 HORSEPOWER	745.7	watts
	0.7457	kilowatt
	33,000	ft.-lbs. per minute
	550	ft.-lbs. per second
	2,546.5	heat units
	42.44	heat units per minute
	0.707	heat units per second
	0.174	lb. carbon oxidized per hour
	2.62	lb. water evap. per hour from and at 212 degrees F.
1 Joule =	1	watt second
	0.000000278	kilowatt hour
	0.102	kilogram meter
	0.0009486	heat unit
	0.73756	ft.-lb.
1 Ft.-Lb.=	1.3558	joules
	0.13826	kilogram meter
	0.0000003766	kilowatt hour
	0.0012861	heat unit
	0.0000005	horsepower hour
1 Watt =	1	joule per second
	0.001341	horsepower
	3.415	heat units per hour
	0.73756	ft.-lb. per second
	0.0035	lb. water evap. per hour
	44.254	ft.-lbs. per minute
1 Watt per Sq. In. =	8.20	heat units per sq. ft. per minute
	6,373	ft.-lbs. per sq. ft. per minute
	0.1931	horsepower per sq. ft.
1 B.T.U. or 1 Heat Unit =	1,054.2	watt seconds
	777.54	ft-lbs.
	107.5	kilogram meters
	0.0002928	kilowatt hour
	0.0003927	horsepower hour
	0.0000685	lb. carbon oxidized
	0.001030	lb. water evap. from and at 212 degrees F.
1 Heat Unit per sq. ft. per min.	1.1220	watt per sq. in.
	0.01757	kilowatt per sq. ft.
	0.02356	horsepower per sq. ft.
1 Kilogram Meter =	7.233	ft.-lbs.
	0.000003653	horsepower hour
	0.000002724	kilowatt hour
	0.009302	heat unit

Unit	Equivalent Value in Other Units	
1 lb. Carbon Oxidized with perfect efficiency=	14,600	heat units
	1.11	lbs. anthracite coal oxidized
	2.5	lbs. dry wood oxidized
	22	cubic feet illuminating gas
	4.275	kilowatt hours
	5.733	horsepower hours
	11,352,000	
	15.05	lbs. of water evap. from and at 212 degrees F.
1 lb. Water Evap. from and at 212 degrees F. =	0.2841	kilowatt hour
	0.3811	horsepower hour
	970.4	heat units
	104,320	kilogram meters
	1,023,000	joules
	754,525	ft.-lbs.
	0.066466	lb. carbon oxidized

MATHEMATICAL FORMULAS USED IN SALES ENGINEERING

ROAD SPEED FORMULAS

$$MPH = \frac{RPM \times r}{R \times 168}$$

$$RPM = \frac{MPH \times R \times 168}{r}$$

$$R = \frac{RPM \times r}{MPH \times 168}$$

$$\text{WHEEL RPM} = \frac{MPH \times 166}{r}$$

TRACTIVE EFFORT FORMULAS

$$TE = \frac{T \times 12 \times R \times E}{r}$$

$$T = \frac{TE \times r}{12 \times R \times E}$$

$$R = \frac{TE \times r}{T \times 12 \times E}$$

TRACTIVE FACTOR FORMULAS

$$TF = \frac{T \times 12 \times R \times E}{GVW \times r}$$

$$T = \frac{TF \times GVW \times r}{12 \times R \times E}$$

$$GVW = \frac{T \times 12 \times R \times E}{TF \times r}$$

$$R = \frac{TF \times GVW \times r}{T \times 12 \times E}$$

GRADE ABILITY FORMULAS

$$GA = TF - RR$$

$$TF = GA + RR$$

$$GA = \frac{T \times 12 \times R \times E}{GVW \times r} - RR$$

$$GVW = \frac{T \times 12 \times R \times E}{TF \times r}$$

$$T = \frac{TF \times GVW \times r}{12 \times R \times E}$$

$$R = \frac{TF \times GVW \times r}{12 \times T \times E}$$

HORSEPOWER FORMULAS

$$IHP = \frac{MEP \times A \times S \times N}{33000 \times C}$$

$$S = \text{Stroke (Ft.)} \times RPM$$

$$IHP = BHP + \text{Friction HP}$$

$$BHP = \frac{BMEP \times A \times S \times N}{33000 \times C}$$

$$BHP = \frac{2 \times RPM \times \pi \times T}{33000}$$

$$BHP = \frac{T \times RPM}{5252}$$

$$BHP = \frac{D \times RPM \times 0.75 \text{ (Approx.)}}{5252}$$

TORQUE FORMULAS

$$T = \frac{D \times BMEP}{150.8}$$

$$T = D \times 0.75 \text{ (Approx.)}$$

$$T = \frac{BHP \times 5252}{RPM}$$

DRAWBAR PULL

$$DBP = TE - RR$$

CLUTCH TORQUE CAPACITY

$$T = \left\{ \begin{array}{l} \text{Total Spring Pressure x} \\ \text{Mean Radius of Lining} \\ \text{x 2 Faces x .25 Coeffi-} \\ \text{cient of Friction} \div 12 \end{array} \right.$$

GRADE ABILITY—HORSEPOWER FORMULAS

$$GA = \frac{33750 \times BHP}{GVW \times MPH} - RR$$

$$GVW = \frac{33750 \times BHP}{MPH \times TF}$$

$$MPH = \frac{33750 \times BHP}{GVW \times TF}$$

$$HP = \frac{GVW \times MPH \times TF}{33750}$$

KEY TO SYMBOLS USED ABOVE

A = Area of piston head in sq. in.
BHP = Brake horsepower.
BMEP = Brake mean effective pressure.
C = No. cycles (4 for IH).
D = Piston displacement in cu. in.
DBP = Drawbar pull.
E = Mechanical efficiency (.90 direct, .85 in other gears).
GA = Grade ability, factor (G x 100 = % Grade).
GVW = Gross weight, lb.
IHP = Indicated horsepower.
MEP = Mean effective pressure.
MPH = Miles per hour.
N = Number of cylinders.
r = Effective tire radius (loaded) (inches)
R = Total reduction to 1.00.
RPM = Engine speed revolutions per minute (r.p.m.)
RR = Rolling or road resistance (.012 lbs. for good concrete roads.
S = Piston speed in feet per minute.
T = Torque—lb.-ft.
TE = Tractive effort, lb.
TF = Tractive factor, lb. per lb. gross.
π = Pi = 3.1416; ratio of diameter to circumference of circle.

POUNDS OF GROSS VEHICLE WEIGHT WHICH ONE HORSEPOWER DELIVERED TO CLUTCH WILL PULL UP VARIOUS GRADES AT VARIOUS SPEEDS

SPEED—MILES PER HOUR

Grade %	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	35	40	45	50	Grade %
0.1												998	962	927	895	865	742	649	577	519	0.1
0.2			MORE THAN								964	928	893	861	832	804	689	603	536	482	0.2
0.3			1000 LBS.						978	938	900	865	834	804	777	750	643	563	500	450	0.3
0.4							1000	958	917	879	844	810	781	753	728	702	603	527	469	422	0.4
0.5						993	947	903	863	827	795	764	736	710	685	662	567	496	441	397	0.5
0.6					988	937	894	853	817	782	750	722	695	670	648	625	536	469	417	375	0.6
0.7				987	935	890	847	808	773	741	711	683	658	635	612	593	507	444	395	355	0.7
0.8			993	936	889	843	803	766	733	702	674	648	625	602	581	561	482	422	375	338	0.8
0.9		1000	945	890	845	802	765	730	698	669	642	617	594	573	553	535	459	402	357	321	0.9
1.0		959	903	854	808	768	730	697	667	639	613	590	567	548	529	511	438	384	341	307	1.0
1.1	978	917	862	813	772	732	697	665	638	611	586	562	542	522	504	488	419	367	326	293	1.1
1.2	937	878	827	782	740	702	670	639	611	586	562	540	521	502	484	469	402	352	313	281	1.2
1.3	900	844	795	750	710	675	643	613	587	563	540	519	500	482	465	450	386	338	300	270	1.3
1.4	867	812	764	722	684	650	619	591	565	542	520	500	481	463	448	433	371	325	288	260	1.4
1.5	833	781	736	694	658	625	595	568	543	521	500	481	462	446	431	410	357	313	278	250	1.5
1.6	803	754	709	670	634	602	573	547	524	502	482	463	446	430	416	401	344	301	268	241	1.6
1.7	776	727	685	647	612	581	554	529	506	484	465	447	431	416	401	388	333	290	259	233	1.7
1.8	750	703	662	625	592	562	536	511	488	468	450	432	416	401	387	375	321	281	250	225	1.8
1.9	727	681	641	606	573	544	519	495	473	453	435	419	403	389	375	363	311	272	242	218	1.9
2.0	703	659	620	586	555	527	502	479	458	439	422	406	390	377	364	352	301	264	234	211	2.0
2.1	680	639	600	567	537	511	486	465	444	425	409	393	378	366	352	341	292	256	227	205	2.1
2.2	661	620	584	551	523	496	473	452	432	414	397	382	368	355	342	331	284	248	221	199	2.2
2.3	642	601	566	535	507	482	459	438	419	401	386	371	357	345	332	322	276	241	214	193	2.3
2.4	625	585	552	520	494	469	446	426	407	391	375	361	348	335	323	312	268	234	208	188	2.4
2.5	608	570	536	507	480	456	434	415	397	380	365	351	338	326	314	304	261	228	203	182	2.5
2.6	591	555	522	493	467	444	423	404	386	370	356	342	329	317	306	296	254	222	197	178	2.6
2.7	576	540	508	480	455	432	412	394	376	360	346	333	320	309	298	288	247	216	192	173	2.7
2.8	561	527	495	468	443	421	401	383	367	351	337	324	312	301	291	281	241	211	188	169	2.8
2.9	548	514	484	457	433	411	392	374	358	343	329	317	304	294	283	274	235	206	183	165	2.9
3.0	535	503	472	446	422	400	382	365	349	334	321	309	297	287	277	268	230	201	179	161	3.0
3.1	523	490	462	436	413	392	374	357	341	327	314	302	290	280	271	262	224	196	174	157	3.1
3.2	511	479	451	425	404	383	365	348	333	319	307	295	284	274	264	256	219	192	170	153	3.2
3.3	500	468	441	416	395	375	357	341	326	312	300	288	277	267	258	250	214	188	167	150	3.3
3.4	489	457	431	407	386	366	349	333	319	305	293	282	272	262	253	244	210	183	163	147	3.4
3.5	478	449	422	399	378	359	342	326	312	299	287	276	266	257	248	239	205	180	160	144	3.5
3.6	468	439	413	390	370	351	334	319	305	292	281	270	260	251	242	234	201	176	156	141	3.6
3.7	458	430	405	382	362	344	327	313	299	287	275	265	255	246	237	229	197	172	153	138	3.7
3.8	450	422	397	375	355	337	321	307	293	281	270	260	250	241	233	225	193	169	150	135	3.8
3.9	441	413	389	367	348	330	315	300	287	275	264	254	245	236	228	221	189	165	147	132	3.9
4.0	432	405	381	360	341	324	309	294	282	270	259	249	240	231	223	216	185	162	144	130	4.0
4.1	424	397	374	353	335	318	303	289	276	265	254	244	236	227	219	212	182	159	142	127	4.1
4.2	416	390	367	347	328	312	297	284	272	260	250	240	231	223	215	208	179	156	139	125	4.2
4.3	409	383	361	341	323	307	292	279	267	255	245	236	227	219	211	204	175	153	136	123	4.3
4.4	401	376	354	335	317	301	287	274	262	251	241	232	223	215	208	200	172	151	134	121	4.4
4.5	394	370	348	328	311	295	282	269	257	246	237	227	219	211	204	197	169	148	132	118	4.5
4.6	387	363	342	323	306	290	277	264	253	242	232	223	217	207	201	194	166	145	129	116	4.6
4.7	381	357	336	318	300	286	272	260	248	238	228	220	212	204	197	191	163	143	127	114	4.7
4.8	375	351	331	312	295	281	268	255	244	234	224	216	208	200	194	188	160	140	125	113	4.8
4.9	369	346	325	307	291	276	263	251	240	231	221	213	205	198	191	184	158	138	123	111	4.9
5.0	363	340	320	302	286	272	259	247	236	226	218	209	202	194	188	181	156	136	121	109	5.0
5.1	357	335	315	298	282	268	255	244	233	223	214	206	198	191	185	179	153	134	119	107	5.1
5.2	351	330	310	293	277	264	251	240	229	220	211	203	195	188	182	176	151	132	117	105	5.2
5.3	346	325	305	289	273	260	247	236	226	216	208	200	192	185	179	173	148	130	115	104	5.3
5.4	341	320	301	284	269	256	244	233	223	213	205	197	189	183	176	170	146	128	114	102	5.4
5.5	336	315	296	280	265	252	240	229	219	210	202	194	187	180	174	168	144	126	112	101	5.5
5.6	331	310	292	276	261	248	236	226	216	207	199	191	184	177	171	165	142	124	110	99	5.6
5.7	326	306	288	272	257	244	233	223	213	204	196	188	181	175	169	163	140	122	109	97	5.7
5.8	321	301	283	268	254	241	229	219	210	200	193	185	179	172	166	161	138	121	107	96	5.8
5.9	317	297	280	264	250	238	226	216	207	198	190	183	176	170	164	158	136	119	106	95	5.9

SPEED—MILES PER HR.

Grade %	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	35	40	45	50	Grade %
6.0	312	293	275	260	246	234	223	213	204	195	188	180	174	167	162	156	134	117	104	94	6.0
6.1	308	289	272	257	243	231	220	210	201	193	185	178	171	165	159	154	132	116	103	92	6.1
6.2	304	285	268	254	240	228	217	207	198	190	182	175	169	163	157	152	130	114	101	91	6.2
6.3	300	281	264	250	237	225	214	204	196	187	180	173	167	161	155	150	129	113	100	90	6.3
6.4	296	278	261	247	234	222	211	202	193	185	178	171	164	159	153	148	127	111	99	89	6.4
6.5	292	274	258	244	230	219	209	199	191	183	175	169	162	156	151	146	125	110	97	88	6.5
6.6	288	270	254	240	227	216	206	197	188	180	173	166	160	154	149	144	124	108	96	86	6.6
6.7	284	266	251	237	224	213	203	194	186	178	171	164	158	153	147	142	122	107	95	85	6.7
6.8	281	263	248	234	221	211	201	192	183	176	169	162	156	151	146	140	121	105	94	84	6.8
6.9	278	260	245	231	219	208	198	189	181	174	167	160	154	149	144	139	119	104	92	83	6.9
7.0	274	257	242	228	216	206	196	187	179	171	165	158	152	147	142	137	118	103	91	82	7.0
7.1	271	254	239	226	214	203	194	184	177	169	163	156	151	145	140	136	116	102	90	81	7.1
7.2	267	251	236	223	211	201	191	182	175	167	161	155	149	143	139	134	115	100	89	80	7.2
7.3	264	248	234	221	209	199	189	180	173	165	159	153	147	142	137	132	113	99	88	79	7.3
7.4	263	245	231	218	207	196	189	178	171	163	157	151	145	140	135	131	112	98	87	78	7.4
7.5	259	242	228	216	204	194	185	176	169	162	155	149	144	139	134	129	111	97	86	77	7.5
7.6	256	240	226	213	202	192	183	174	167	160	153	148	142	137	132	128	110	96	85	77	7.6
7.7	253	237	223	211	200	190	181	172	165	158	152	146	140	135	131	126	108	95	84	76	7.7
7.8	250	234	221	208	197	188	179	170	163	156	150	144	139	134	129	125	107	94	83	75	7.8
7.9	248	232	218	206	195	185	177	169	161	155	148	143	137	132	128	124	106	93	82	74	7.9
8.0	245	229	216	204	193	183	175	167	159	153	147	141	136	131	127	122	105	92	81	73	8.0
8.1	242	227	213	202	191	182	173	165	158	151	145	140	134	130	125	121	104	91	81	72	8.1
8.2	239	224	211	199	189	180	171	163	156	150	144	138	133	128	124	120	103	90	80	72	8.2
8.3	236	222	209	197	187	178	169	161	154	148	142	137	132	127	122	118	102	89	79	71	8.3
8.4	234	220	207	195	185	176	167	160	153	146	141	135	130	126	121	117	100	88	78	70	8.4
8.5	232	217	205	193	183	174	166	158	151	145	139	134	129	124	120	116	99	87	77	69	8.5
8.6	230	215	203	191	181	172	164	157	150	143	138	132	128	123	119	115	98	86	76	69	8.6
8.7	227	213	201	189	179	171	162	155	148	142	137	131	126	122	118	114	97	85	76	68	8.7
8.8	225	211	199	188	178	169	160	153	147	141	136	130	125	121	116	113	96	84	75	67	8.8
8.9	223	209	197	186	176	167	159	152	145	139	134	129	124	119	115	111	95	83	74	67	8.9
9.0	220	207	195	184	174	165	158	150	144	138	132	127	123	118	114	110	94	83	73	66	9.0
9.1	218	205	193	182	172	164	156	149	142	137	131	126	121	117	113	109	94	82	73	65	9.1
9.2	216	203	191	180	171	162	155	148	141	135	130	125	120	116	112	108	93	81	72	65	9.2
9.3	214	201	189	179	169	161	153	146	140	134	129	124	119	115	111	107	92	80	71	64	9.3
9.4	212	199	187	177	168	159	152	145	138	133	127	122	118	114	110	106	91	79	71	64	9.4
9.5	210	197	186	175	166	158	150	143	137	131	126	121	117	113	109	105	90	79	70	63	9.5
9.6	208	195	184	174	164	156	149	142	136	130	125	120	116	112	108	104	89	78	69	62	9.6
9.7	206	193	182	172	163	155	147	141	135	129	124	119	115	111	107	103	88	77	69	62	9.7
9.8	204	192	180	170	161	153	146	139	133	128	123	118	114	110	106	102	88	77	68	61	9.8
9.9	202	190	179	169	160	152	145	138	132	127	122	117	113	109	105	101	87	76	67	61	9.9
10.0	201	188	177	167	159	151	143	137	131	126	120	116	112	108	104	100	86	75	67	60	10.0

ROAD—ENGINE SPEED FORMULAS

S —Road speed in miles per hour.
RPM—Engine speed in revolutions per minute.
r —Tire rolling radius in inches.
R —Total gear reduction = Rear axle ratio x Transmission ratio.

ABILITY FORMULAS

GVW—Gross weight of vehicle (or combination) in pounds.
S —Road speed in miles per hour.
HP —Power delivered to clutch at road speed S in particular transmission ratio being used.
G —Grade in per cent.

In the following ability formulas, a value of 1.2 lbs. per 100 lbs. of gross weight is used for rolling resistance. Power lost in overcoming friction between the clutch and the driving wheels is taken at 0.1 of the power delivered to the clutch by the engine and an efficiency factor of 0.9 has accordingly been incorporated in the formulas.

1—$GVW = \frac{33750 \times HP}{S(G+1.2)}$

2—$\frac{GVW}{HP} = \frac{33750}{S(G+1.2)}$ = Lbs. per Horsepower

3—$S = \frac{33750 \times HP}{GVW\ (G+1.2)}$

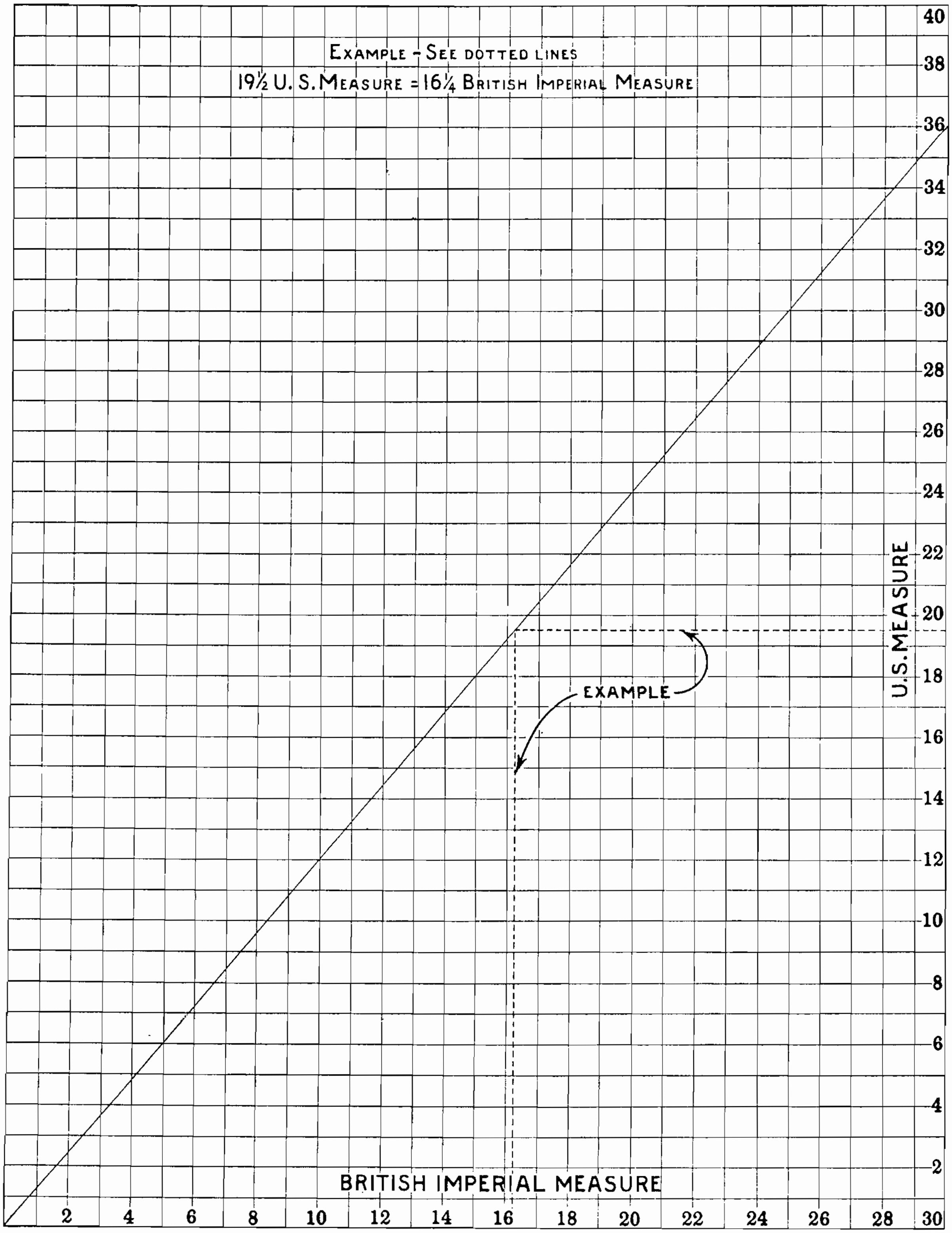
4—$G = \frac{33750 \times HP}{GVW \times S} - 1.2$

5—$S = \frac{RPM \times r}{168 \times R}$

6—$RPM = \frac{168 \times R \times S}{r}$

CONVERSION CHART—LIQUIDS

BRITISH IMPERIAL and U.S. MEASURE



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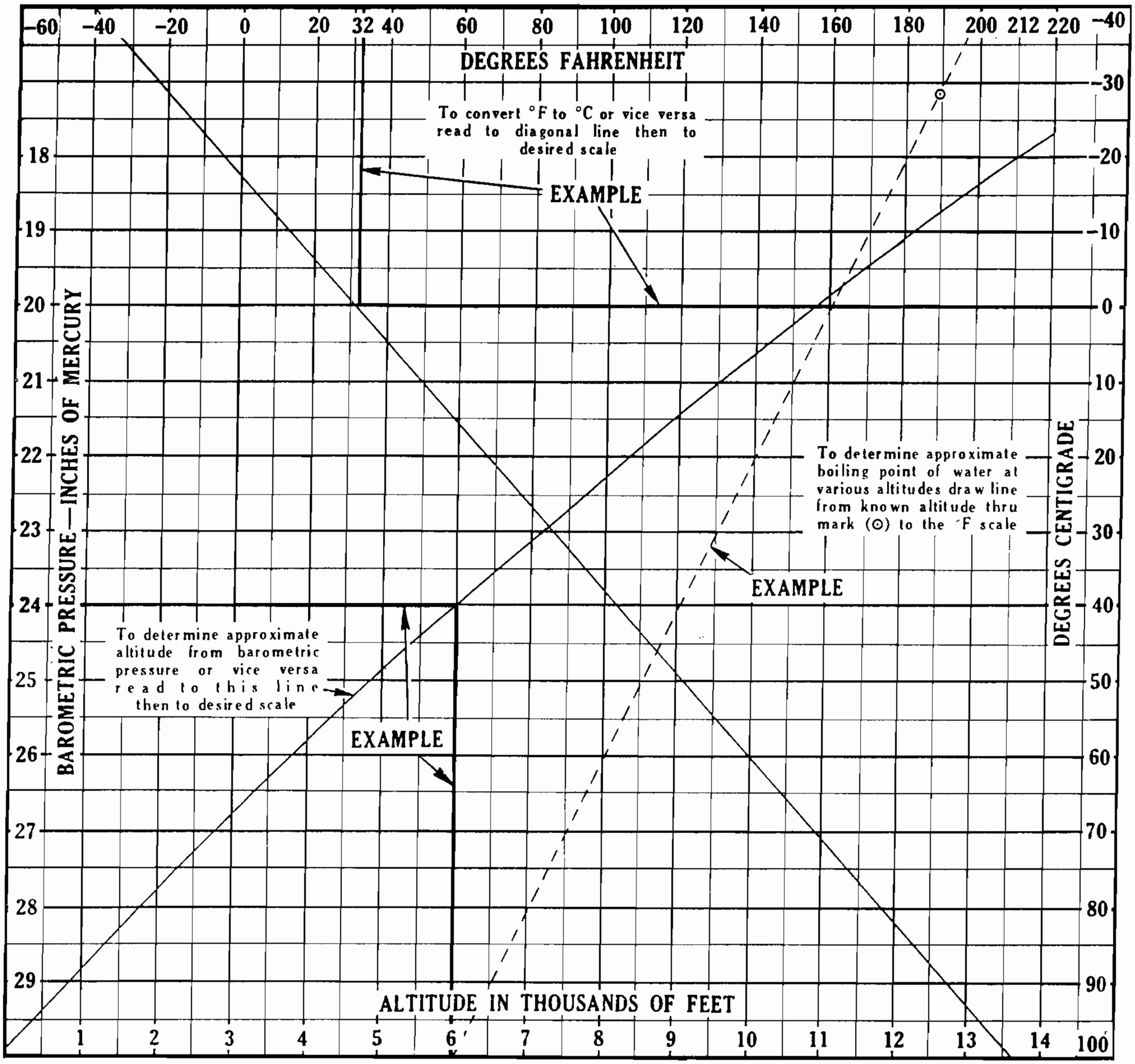
DEGREES FAHRENHEIT
-60 -40 -20 0 20 32 40 60 80 100 120 140 160 180 200 212 220
To convert °F to °C or vice versa read to diagonal line then to desired scale
EXAMPLE
To determine approximate boiling point of water at various altitudes draw line from known altitude thru mark (⊙) to the °F scale
EXAMPLE
To determine approximate altitude from barometric pressure or vice versa read to this line then to desired scale
EXAMPLE
BAROMETRIC PRESSURE—INCHES OF MERCURY
18 19 20 21 22 23 24 25 26 27 28 29
DEGREES CENTIGRADE
-40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
ALTITUDE IN THOUSANDS OF FEET
1 2 3 4 5 6 7 8 9 10 11 12 13 14

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