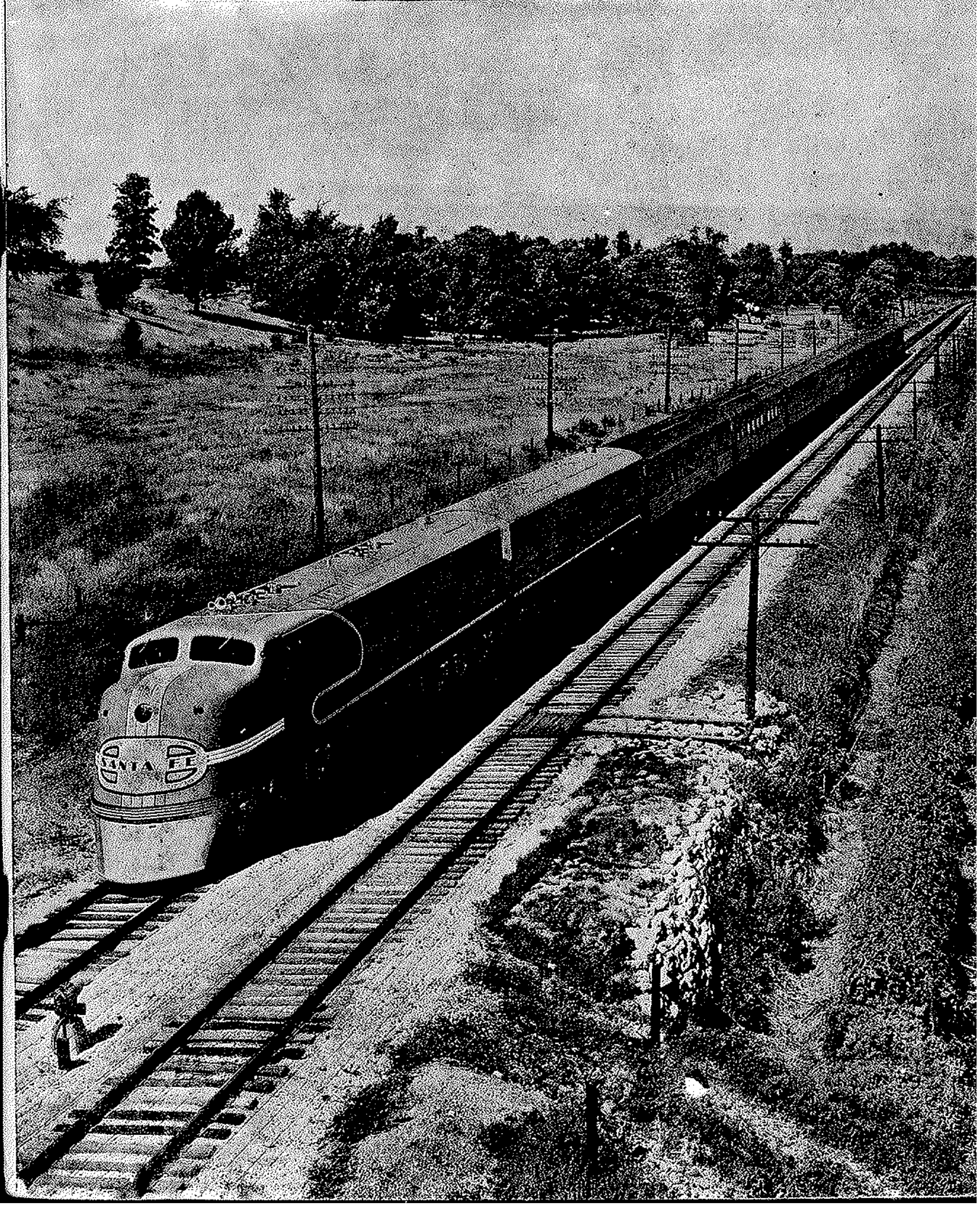
The

(No. 4)

Santa Fe Today



The Santa Fe Today—No. 4

Explanatory note: Expansion of the Santa Fe from a small Kansas enterprise into a vast transcontinental transportation system has brought about many changes in its operations. This article is the fourth in a series to explain the workings of this modern railroad plant with its shops, yards, offices and other physical properties which go to make up the Santa Fe today. These articles have been prepared by Leo J. Martin of the public relations department with the co-operation of the various department heads and the editors of The Santa Fe Magazine. The remaining articles in the series will be published and distributed from time to time until all departments of the railroad have been included.

Employees are urged to retain this pamphlet and all others in the series so that at the conclusion they may have a complete story of The Santa Fe Today.

The Santa Fe Today

The Mechanical Department

THE mechanical department is the responsibility of the vice-president in charge of operation. The Santa Fe's chief mechanical officer, J. M. Nicholson, assistant to vice-president, Chicago, is charged with the supervision of the some 20,000 Santa Fe men and women who complement the mechanical department, the maintenance and inspection of Santa Fe motive power and passenger, freight and work car equipment, the maintenance and supervision of shop and roadway mechanical facilities on the system lines, all necessary repairs to foreign cars while on Santa Fe rails, and special inspection of cars reaching the Santa Fe or leaving Santa Fe rails at interchange points.

In the acquisition of new locomotive and car equipment, the mechanical department prepares designs and specifications. This procedure often is followed in the acquisition of various machines and other facilities necessary to maintain Santa Fe power and mechanical equipment. Improvements that have been found practicable are made on certain classes of locomotives and cars. Where conditions justify, equipment requiring heavy repairs is repaired in kind; other similar equipment of older design is rebuilt to embody improvements and developments originated since the equipment was first built.

Shop maintenance includes Santa Fe power plants and all establishments within Santa Fe shop areas, totaling some 1,800 acres, with full complement of machinery and machine tools in addition to various roadway machines. The Santa Fe has approximately 1,800 steam and Diesel locomotives, 81,000 freight cars, 1,435 passenger cars, 6,000 pieces of work equipment, three tugs and four car floats.

Uniformity of practice has been characteristic of the Santa Fe's mechanical department since 1913 when John Purcell, retired mechanical department head, introduced the Santa Fe's celebrated folio method by which system mechanical instructions covering the maintenance of Santa Fe equipment and tested and approved methods are embodied in loose-leaf folios of identical content located at each point on the Santa Fe system where a need for them might arise. The most popular of these folios are the Locomotive, Diesel, Car and Welding. There are many other folios applicable to specialized Santa Fe procedures such as the Paint, Steel, Abrasive, Packing Leather and others. Printed books issued by the mechanical department include the important Instructions for Enginemen, governing the care, maintenance and economical operation of the steam locomotive; instructions for operating and maintaining air brake equipment; care of

J. M. NICHOLSON, assistant to vice-president, operation, who is in charge of the mechanical department, with headquarters in Chicago.

locomotive oil-burning equipment; care of steam boilers, air reservoirs and appurtenances thereto; lubrication of locomotives and cars; painting, cleaning, fumigating and sanitation of passenger, freight and work equipment cars and locomotives; care and operation of gas-electric motor cars and motor cars.

Individual instructions, by letter and bulletin, are issued as they always have been since the first years of the mechanical department. Those instructions concern newly developed maintenance practices and special work required on stated equipment, All Interstate Commerce Commission rules

Santa Fe pioneering strides in the use of streamlined equipment and Diesel-electric motive power. The first to use Diesel power in road freight service, the Santa Fe designed important improvements as experience was gained in that comparatively new development in railway motive power. Several hundred Santa Fe men have been trained to supervise and maintain Diesel equipment. Special Diesel shops have been constructed and equipped.

The many mechanical innovations which the Santa Fe has contributed to railroading, past and present, stems from a policy of not being content with the mediocre, and an

Chief Mechanical Officers of the A., T. & S. F. Ry.

Harry V. Faries
Master Mechanic
July 1, 1870—Nov. 30, 1878

George Hackney
Superintendent of Machinery
Nov. 1, 1878—July 1, 1889

Harvey Middletun
Superintendent of Machinery
July 1, 1889—May 31, 1890

John Player
Superintendent of Machinery
June 1, 1890—Jan. 1, 1902

and regulations and all U. S. Safety Appliance Acts for all classes of cars and locomotives engaged in interstate commerce are fully respected in all mechanical department procedures.

The Santa Fe's mechanical department has enjoyed commendable progresssince the turn of the century. In 1907, engine failures totaled 12,147, one for each 4,222 miles traveled. By 1931, the figure had been reduced to 528 or one failure for each 97,780 miles. In 1940, there were 589 engine failures, one for each 92,800 miles. By improvement in design, many innovations, and standardization of locomotives into the Pacific, Mountain, Mikado and Santa Fe types, the mechanical department made possible steam locomotive runs without change from the long established 112 miles up to 1,800 miles and more.

This nation has followed closely the unwillingness to accept failures and unsatisfactory results without exhaustive efforts toward improvements. Santa Fe mechanical officers serve on various committees within the Association of American Railroads. They are active participants in the work of national organizations devoted to the mechanical sciences.

General Mechanical Assistant J. P. Morris, Chicago, assists in the supervision, operation and maintenance of Santa Fe equipment, including power plant, shop machinery and machine tools, and has direct supervision of Deisel-electric locomotives in road and switching service on the system lines.

Mechanical Assistant (engineering and research) E. E. Chapman, Chicago, handles research, tests and inspections, keeps material specifications in line, sees that they are consistent with improvements in the manufacture of various material, and that all material meets specifications. This involves collaboration with the purchasing department, so that developments in material and materiel may be followed; and with the engineering department in the various problems the respective departments have in common. Improvements of locomotives, locomotive accessories, cars and car parts, shop and power plant facilities are investigated as are presented for consideration. The performance of wheels (car and locomotive) are followed. Water treatment and lubrication are other specialties handled by the mechanical assistant, also the Santa

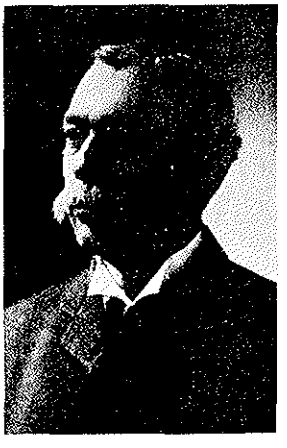
improvements, cost and maintenance reductions, are continuous.

In addition to those officers and staffs, the Santa Fe's mechanical department has the following special departments:

Mechanical engineer, Topeka.
Engineer car construction, Topeka.
Engineer tests, Topeka.
Engineer shop extensions, Topeka.
Fuel conservation engineer, Topeka.
Supervisor of air brakes, Topeka.
Car lighting and air conditioning engineer, Topeka.
Supervisor of Diesel engines, Chicago.
General boiler inspector. Topeka.

Company from its inception to December 31, 1941

George R. Henderson
Superintendent Motive Power
Jan. 1, 1902—July 31, 1903



Alfred Lovell
Superintendent Motive Power
July 31, 1903—Dec. 1, 1907

W. F. Buck
Superintendent Motive Power
Jan. 1. 1908—Jan. 31, 1912

John Purcell
Assistant to Vice-President
May 1. 1912—Dec. 31, 1941

Fe's *fire* rules. Throughout all Santa Fe shops there are planned "fire" roads; on depot platforms, bridges and other structures, the familiar water barrel. Back of those practical steps to fight fires on Santa Fe properties are organized battalions and the official *fire* rules.

Mechanical Assistant R. D. Bryan, Chicago, supervises design, maintenance and performance of all classes of freight, passenger and work cars, including foreign cars on Santa Fe rails. He contacts the representatives of contractors, inventors, manufacturers and jobbers who supply the Santa Fe's construction, improvement and maintenance needs, as well as the engineering staffs of car builders in relation to cars being constructed for the Santa Fe. New and improved devices are investigated, test applications recommended and arranged. Studies and research in regard to service

Supervisor of tools, Topeka
Supervisor of welding, Topeka.
Supervisor of mechanical drawing, Topeka.
Mechanical valuation engineer, Topeka.
General material inspector, Chicago.
General mechanical inspector, Topeka.
General car inspector, Topeka.
Chief scale inspector, Topeka.
Lubricating supervisors, Toyeka and Los Angeles.
Power plant and electric equipment supervisor and inspector.

The organization and functions of those departments, most of which are systemwide in scope, will be detailed in chapters immediately following. In departmental procedure, all report directly to the assistant to vice-president.

The Santa Fe's motive power performance in World War II is a prideful chapter in Santa Fe history, just as Santa Fe contributions to railway mechanics have done much to increase safety and economy by eliminating hazards and waste in railway operations. Always of interest is a railway's mechanical department in action—servicing, repairing and overhauling equipment, inspecting trains, handling engine crews, supplying motive power, and the many other detailed functions essential to proper and expeditious handling of power and equipment demands. The following Santa Fe officers, reporting to the assistant to vice-president, have jurisdiction over the various Santa Fe shop facilities and division master mechanics as designated:

The superintendent of shops, Topeka. The Santa Fe's largest shops are located at Topeka. Much system work is done here. Locomotives receive general repairs (steam). Passenger cars are reconditioned and when advisable ar rebuilt. Extensive freight car rebuilding programs are handled to completion.

Mechanical superintendent, Shopton, Iowa, supervising the Eastern District of the Eastern Lines, including the superintendent shops, Chicago ear works, and division master mechanics at Chicago and Shopton.

Mechanical superintendent, Topeka, supervising the Western District of the Eastern Lines, including the superintendent shops, West Wichita, and division master mechanics at Argentine, Channte, Newton and Arkansas City.

Mechanical superintendent, LaJunta, supervising the Northern District of the Western Lines, and division master mechanics at Dodge City, LaJunta and Albuquerque.

Mechanical superintendent, Amarillo, supervising the Southern District of the Western Lines, and superintendent shops, Albuquerque, and division master mechanics at Wellington, Amarillo, Slaton and Clovis.

Mechanical superintendent, Galveston, supervising the Gulf Lines and division master mechanics at Cleburne, Temple and Galveston and Cleburne shops.

Mechanical superintendent, Los Angeles, supervising the Coast Lines including the superintendent shops, San Bernardino, and division master mechanics at Winslow, Needles, San Bernardino and Calwa, and assistant master mechanics at Winslow and Richmond.

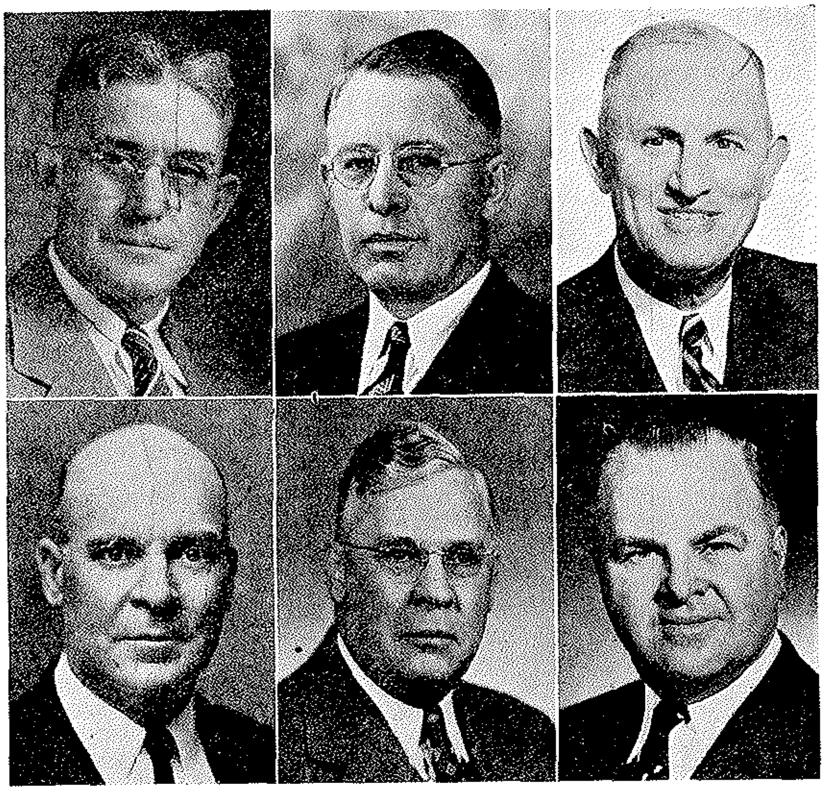
The duties and responsibilities of each mechanical superintendent include the assurance that all mechanical department forces within his territory comply with Interstate Commerce Commission rulings, established Santa Fe rules, and all other instructions issued by the Santa Fe system mechanical officers. The mechanical superintendent handles with the general manager those operating conditions on the territory which involve the mechanical department, and, in conjunction with the assistant general manager, must see that power and equipment are available when needed to handle all traffic presented, and that such power and equipment are in condition to perform necessary services without failures or delays. The co-operation in turn is extended to each superintendent hy the division's master mechanic.

It is necessary that the mechanical superintendent keep well abreast of the power situation throughout his territory, avoiding abundance here and scarcity there. In his frequent travels over the territory, the mechanical superintendent discusses the aower situation with his master mechanic; and superintendent of shops, seeing that they are well versed on immediate conditions and that instructions covering power maintenance and care are followed. Power and equipment maintenance and availability are all-important functions of the mechanical department.

The various mechanical department supervisors and inspectors working on the

SANTA FE MECHANICAL OFFICERS with headquarters in Chicago are, left to right, J. P. Morris, general mechanical assistant; E. E. Chapman, mechanical assistant; R. D. Bryan, mechanical assistant, and Dan Culbertson, general material inspector.

grand divisions but reporting only indirectly to the mechanical superintendent—fuel, air brake, hoiler, welding, lubricating and other supervisors and inspectors—must keep in touch with the mechanical superintendent reporting any irregularities they find and working with him in the application of proper and speedy remedies.

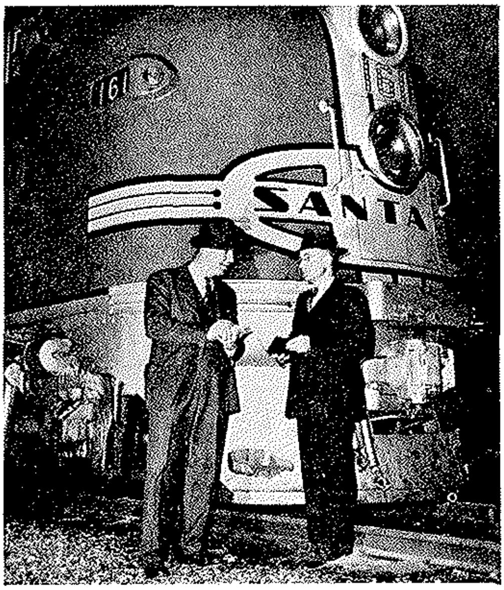


MECHANICAL SUPERINTENDENTS, left to right—J. W. Atkinson, Eastern District, Shopton, la.; W. D. Hartley, Western District, Topeka, Kan.; W. R. Harrison, Southern District, Amarillo, Tex.; P. J. Danneberg, Northern District, La Junta, Colo.; W. P. Hartman, coast Lines, Los Angeles, Cal.; O. G. Pierson, Gulf Lines, Galveston, Tex.

The mechanical superintendent must see that all personnel under him are informed in regard to mechanical practices, changes in construction design and changes in operating conditions which arise, that all are alert in safeguarding the interests of Santa Fe patrons with respect to service needs. Because his territory is large and many operations are constant within the area, the mechanical superintendent must he familiar with conditions at many points and be able authoritatively to meet current problems and cniergencies, knowing that his authority and decisions are final within the territory.

The Santa Fe's largest shops are located at Topeka, Albuquerque, Cleburne and San Bernardino. Large shops also are located at Shopton, Argentine, LaJunta, Clovis and Richmond. Other shops are located on local divisions in conjunction with roundhouse, turntable and other facilities—each under the direction of a master mechanic. At points on a local division where no master mechanic is located, mechanical department forces are in charge of division foremen, to whom the day and night roundhouse, car and other foremen report. At Richmond and Winslow, because of heavy power assignments, there are assistant master mechanics. The Chicago car works and West Wichita shops are directed by a superintendent of shops.

Each master mechanic is responsible for the daily motive power requirements on his division., In that respect, he works closely with the division superintendent. The master mechanic maintains locomotives assigned to his division, including steam, Diesel and motor cars. That involves daily running repairs, classified shopping and general repairs, and preparation of forms to cover shopping of locomotives. All locomotives are inspected and maintained in accordance with Interstate Commerce Commission requirements. The master mechanic maintains the personal record files of shop and enginemen, keeps daily record of changes in assignments, advertising vacancies and handling assignments of engineers and firemen. In all matters pertaining to the mechanical department, enginemen report to and receive their instructions from the master mechanic. Before departing on a run, enginemen must know that their engine is in good working order and that it is furnished with fuel, water, tools, sand and other supplies including signal appliances—all of which are responsibilities of the master mechanic's staff.



Master mechanics work closely with operating department officials in many respects. Here we see *S. S. Rose (left), trainmaster* of the *Missouri* Division, and Gomer Jones (right), master mechanic, conversing beside a Diesel locomotive at Shopton, Ia.

The Santa Fe's steam locomotives (Mikado, Consolidation, Prairie, Pacific, Mountain and Santa Fe types) in freight service, run approximately 35,000 to 45,000 miles after receiving general repairs before being held for Class-5-light or Class-5-heavy repairs. After making 35,000 to 45,000 additional miles or a total of 80,000 miles, they are held for Class-5-heavy repairs in order to complete the mileage necessary before sending to one of the Santa Fe's large shops (Topeka, San Bernardino, Cleburne or Albuquerque) for general repairs at approximately 120,000 to 126,000 miles. Passenger steam locomotives usually make 70,000 to 80,000 miles after receiving general repairs until held for driving box and other necessary work, this cycle being followed by another 70,000 to 80,000 miles, after which the locomotives are sent to a large shop for general repairs. Roller bearing equipped engines run 350,000 to 400,000 miles before receiving general repairs.

Repairs to locomotives which are performed in the roundhouse or in the backshop adjacent thereto are classified as follows:

Class 1. New boiler, or new back end. Flues new or reset and electric welded. Tires turned or new. General repairs to machinery and tender.

Class 2. New firebox, or one or more shell courses, or roof sheet. Flues new or reset and electric welded. Tires turned or new. General repairs to machinery and tender.

Class 3. Necessary repairs to boiler and firebox. Flues all new or reset and electric welded. Tires turned or new. General repairs to machinery and tender.

Class 4. Light repairs to boiler or firebox. Flues all reset and electric welded. If necessary, tires turned or new. General repairs to machinery and tender.

Class 5. (Heavy). Light repairs to boiler or firebox. Repair flues where necessary. Renew or turn driving tires. Drop all drivers. Refit boxes, take up lateral. Overhaul rods, valve gear, spring and brake rigging, guides, pistons, engine trucks and trailers.

Class 5. (Light). Light repairs to boiler or firebox. Repair flues where necessary. Drop main drivers and other drivers where necessary. Refit boxes, take up lateral. Overhaul rods, valve gear, spring and brake rigging, guides, pistons, engine trucks and trailers.

Running repairs. All other repairs are so classed.

General repairs. General repairs to machinery, as specified for classes 1, 2 and 3, will include all necessary turning, changing, overhauling, and refitting or renewing driving wheels, journals, driving boxes, bearings and rods, and all other repairs necessary for a full term of service, or to perform mileage expected between shoppings.

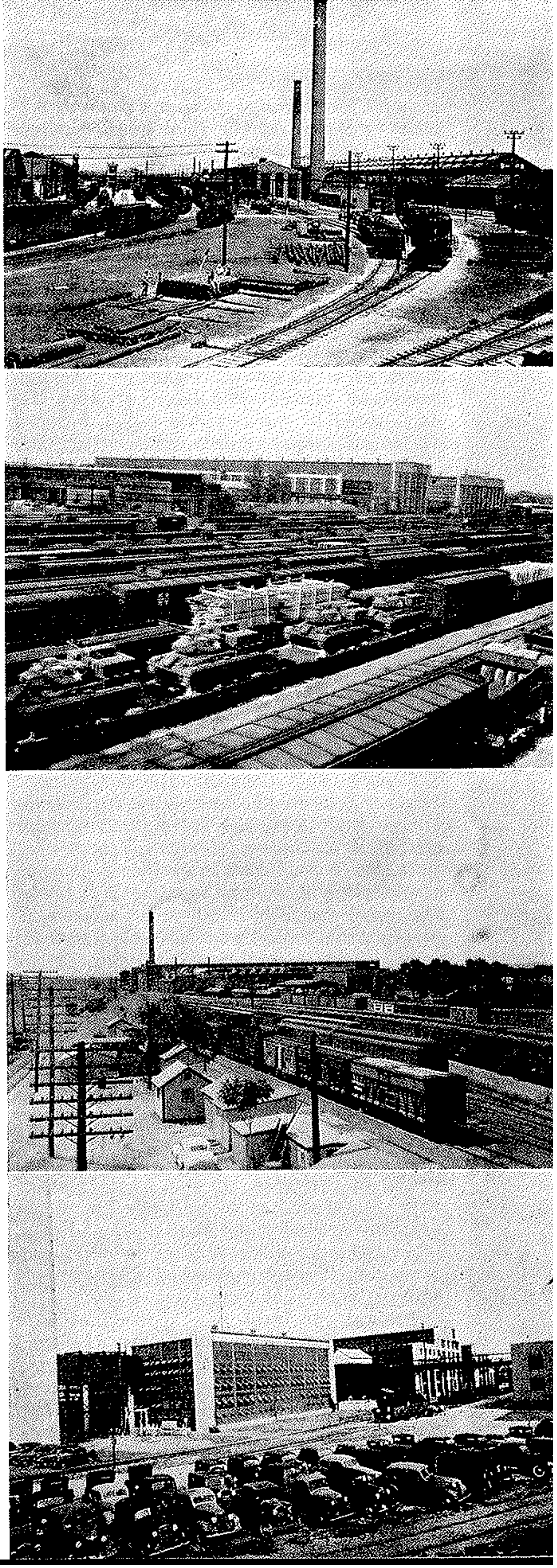
Mileage is started anew when engines are shopped for class 1, 2 or 3 repairs. Special repairs are indicated by suffixes to the repair class number as follows: W-wreck, X-extraordinary, A-initial application of stoker, B-initial application of superheater, C-initial application of outside valve gear, D-initial application of feed water heater, E-converted from compound to simple, or one type to another, F-converted from coal to oil or vice-versa.

Arriving at incoming pit at the master mechanic's roundhouse, the locomotive is first inspected for steam blows, pounds, lateral, loose parts, and general condition. A sample is taken of the boiler water. Locomotive is then moved to wash rack and cleaned. On coal burning engines the fire is knocked. Taken into the roundhouse, the locomotive is checked by the inside inspector for general mechanical condition, loose parts and other defects in connection with

Federal inspection. The engineer has noted his findings on the standard Locomotive Inspection Report and the outside inspector has noted the station, time and date. The inside inspector now enters work items on report and by means of work slips distributes the work to assigned men in the roundhouse. After the work is completed, all factors are checked and approved by the foreman. Upon being ordered for service, the locomotive is taken to outgoing lead where it is supplied with necessary equipment — lubricating oil, tools, fusees, flags, torpedoes — then to the coal chute for coal or oil crane for oil, water and sand. Enginemen must check the locomotive, the various gauges, water glass, grate levers, and must determine if work reported as necessary has been properly taken care of by the master mechanic's forces.

The master mechanic also is charged with maintenance and inspection of all classes of freight cars which reach his shops, including inspection and minor repairs to equipment in passing trains. Repairs to freight cars are designated as light, medium or heavy. Cars are inspected and maintained in accordance with U. S. Safety Appliance Act. The master mechanic's facilities usually include a roundhouse, backshop, blacksmith shop, car shop, air brake shop, freight car shop, power plant, acetylene gas generating plant, turntable, transfer table, drop-pit table in roundhouse, apprentice school, and inspection pits on main line to service through passenger locomotives. Some Santa Fe master mechanics have Lidgerwood tire-turning facilities. Each has a sizeable office staff which, in addition to pay rolls and personnel records, handles a volume of statements and reports including Federal inspections of engines and motor cars, engine and firebox mileage, axles, crank pins and other parts, out-of-service and repair records, staybolt diagrams, semi-monthly assignment and transfer of engines, firebox report, hotbox report, bad order cars on hand, shop working hours, engine failures (which cost over $150), engines shopped, roundhouse operations, power house operating expenses and many others. At Shopton, data is compiled on automatic train control operations on the Illinois Divisions.

The master mechanic's staff includes a



The Santa Fe's largest shops are located at (top to bottom), Topeka, Kan., San Bernardino, Cal., Albuquerque, N. M., and Cleburne, Tex. Large shops also are located at Shopton, Ia., Argentine, Kan., La Junta, Colo., Clovis, N. M., and Richmond, Cal.

general foreman and a day roundhouse foreman in charge of the roundhouse who assigns engine crews, hostlers and power, maintaining close contact with the chief dispatcher in regard to trains and classes of power required to protect them. The various procedures, running repairs, drop pit, erecting, material, tool, boiler and others, have assigned crews and foremen. The night roundhouse foremen and staff duplicate the day procedure. A general car foreman supervises inspcction and maintenance of all classes of freight cars, including light, medium and heavy repairs. He is assisted by various crews and foremen including train yard foremen (day and night) who supervise inspcction of both freight and passenger trains.

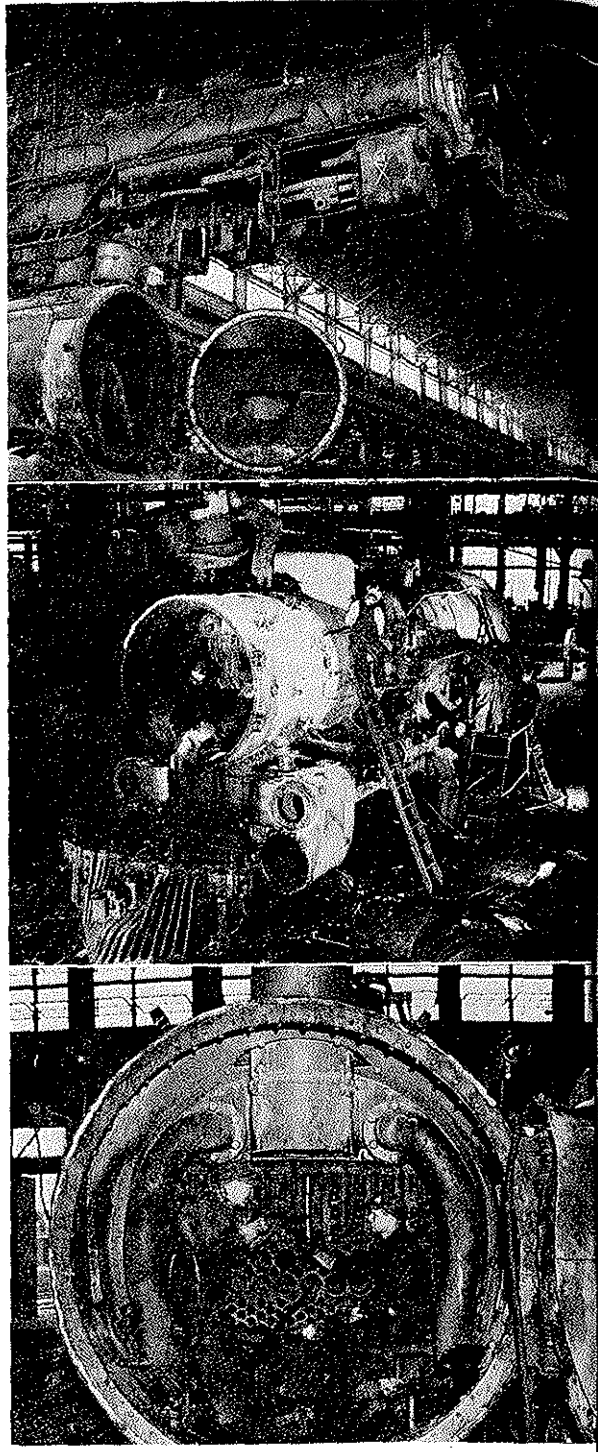
When one of our passenger trains arrives at its destination, say Chicago, a switch engine couples into the back end of the train and pulls it to the passenger yard for inspection, any needed repairs, cleaning and servicing for its next trip. In order to make a thorough inspection of the trucks and their various parts, also all the underneath part of the car, one of the tracks has a pit between the rails long enough to set the whole train over it. This is called the inspection pit, and it is deep and wide enough for men to walk along underneath the train, is electric lighted so as to give ample light for the man to see any defects in the under part of the cars.

It also is used to make various repairs on the trucks and underneath side, as many of the repairs can be made much more efficiently than could be made in the old-fashioned way of a man crawling under the car or trucks and lying flat on his hack to make the repairs.

These modern inspection pits arc a long step forward in the servicing of the modern and streamlined passenger trains of today and the future. It provides a much more efficient way of inspection, as any defects or defects in the making can readily be seen as the men walk along underneath the full length of the train. In the old days all of this inspection had to he made by a man crawling around under the trucks and cars, often through water, mud or snow; therefore, defects were overlooked which caused serious trouble later on.

Freight car inspection is made at each division point. Blue signals are displayed at each end of train and inspectors and oilers tag bad order cars.

Each master mechanic has one or two road foremen of engines who are respon-



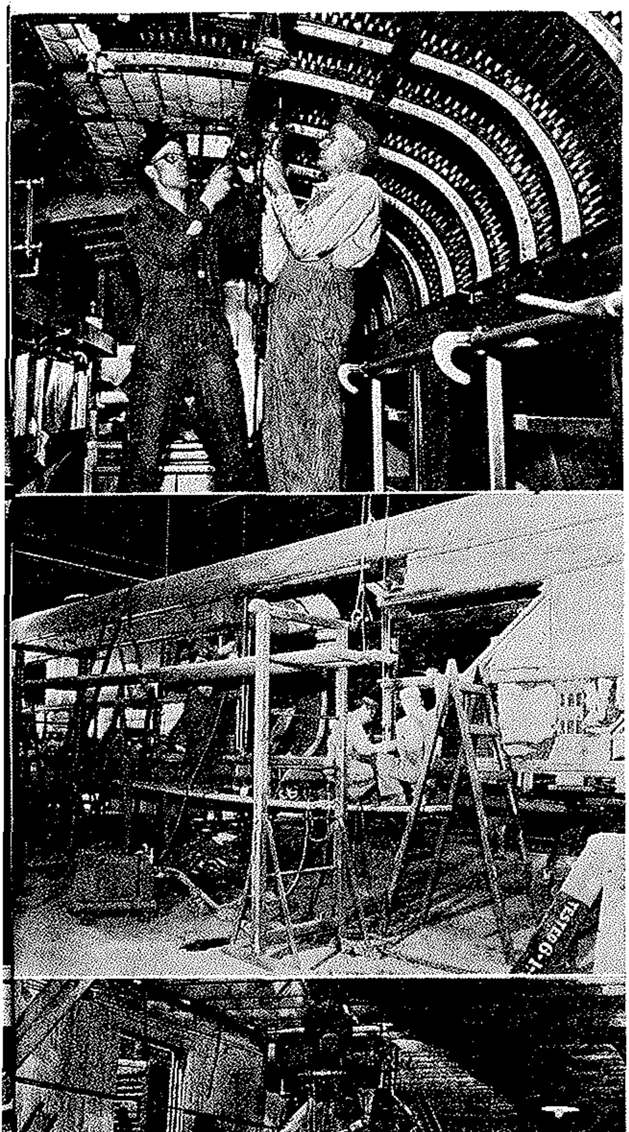
Views of three operations in locomotive department of shops. Top — After engine has been lifted from its wheels, a crane moves it through shop to point where it will be dismantled. Center—Mechanics on ladders and moveable platforms strip the iron horse of its outer raiment. Bottom—Removing superheater tubes.

sible for the correct operation of locomotives. They ride the locomotives observing enginemen, note general handling and observance of rules. They report on power conditions, instruct newly employed firemen and handle oral first and second year mechanical examinations of the latter. Road foremen represent the mechanical department in formal investigations conducted by the division superintendent or trainmaster. They also make daily reports of work necessary on locomotives they inspect and ride, meeting monthly with master mechanic and roundhouse foreman for general discussion on the power situation.

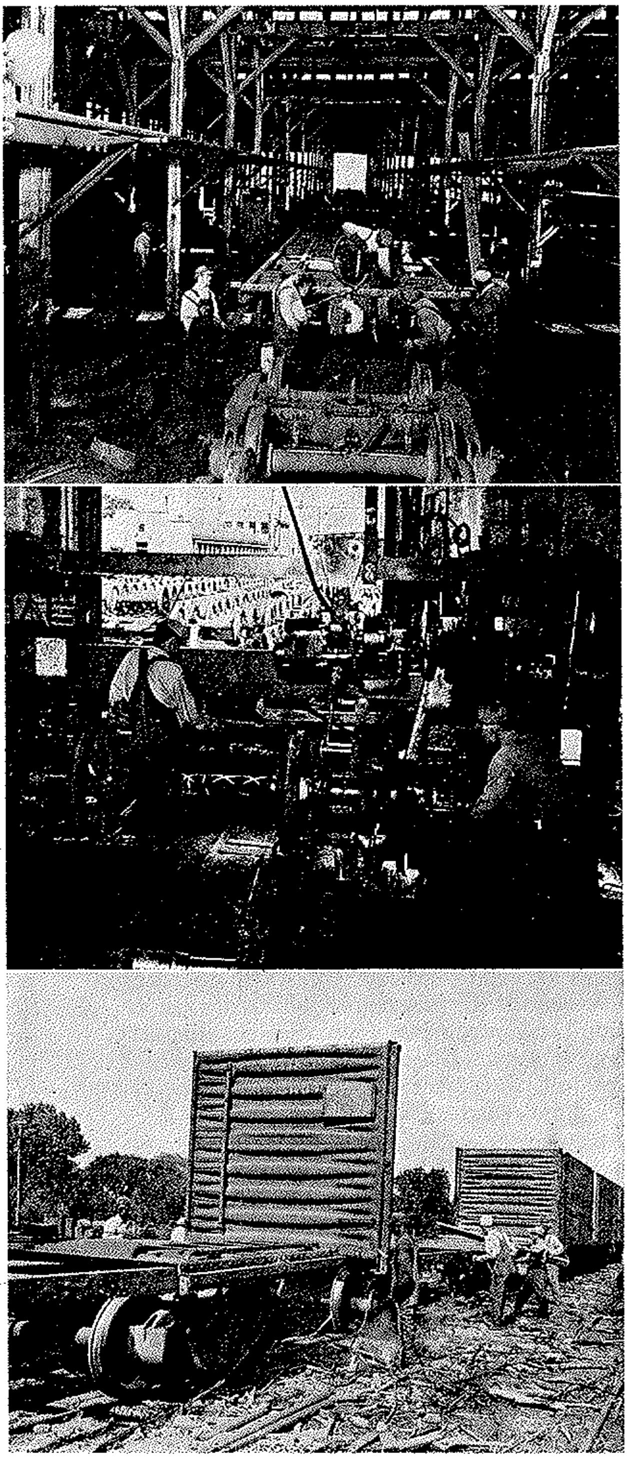
The master mechanic is chairman of the mechanical department safety committee, conducting quarterly meetings, as well as monthly meetings with all his supervisors to discuss individually each apprentice employed locally. He makes occasional trips over the division, riding special trains or locomotives, including new ones and those equipped with new or test appliances. He conducts formal and informal investigations within the scope of his authority and represents the mechanical department in such investigations conducted by operating department officials.

At the Topeka shops, which also embrace generally all the procedures at the Santa Fe's San Bernardino, Cleburne and Albuquerque shops, the task of general repairs to steam locomotives, reconditioning of passenger cars, rebuilding of freight cars, and many other mechanical department procedures are centered. The Topeka shops cover 119 acres, thirty acres of which are under roof, and comprise four distinct departments: locomotive, passenger ear, freight car, and water service. The latter includes work and roadway equipment repair.

In the locomotive department which includes the machine shop, erecting floor, forge, blacksmith and boiler shops, tool room and blue print room, some 900 Santa Fe machinists, electricians, carpenters, sheet metal workers, boiler makers, welders, blacksmiths, painters, helpers and apprentices do general repairs to all steam locomotives assigned to the Santa Fe's Eastern Lines and part of the Northern District of the Western Lines; also miscellaneous shop work for the Santa Fe system, including such items as main and side rods, draw bars, valve motion parts and miscellaneous machine castings of brass, steel and gray iron for locomotive repairs at various Santa Fe shops. At San Bernardino, locomotives assigned to the Coast Lines except freight



Three views of operations in passenger car department of shops. Top—Merle Prettyman and J. E. Walker, coach carpenters, Topeka, repairing dining car. Center—Repairing exterior of the same dining car. Bottom—Repairing passenger car trucks in Topeka shops. Left to W. Minson and Oscar Walstrom, carmen.



Three views of operations in freight car department of the Topeka shops. Top—A typical workaday scene in the interior of the freight car shops. Center—A corner of the wheel room, showing H. B. Schwartz, wheel foreman, at right. Bottom—Workmen engaged in cutting end off freight car for reconditioning.

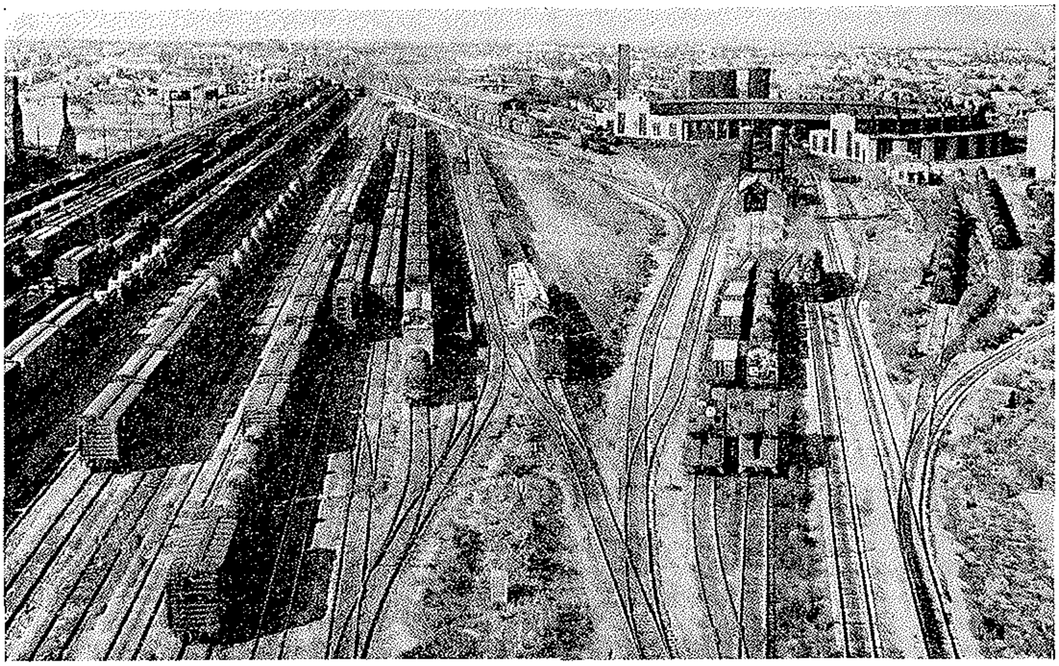
locomotives east of Winslow receive general repairs; at Albuquerque, those assigned to the Southern District of the Western Lines and freight locomotives operating on the Coast Lines east of Winslow; at Cleburne, those assigned to the Gulf Lines.

The thorough treatment given a locomotive arriving at Topeka shops for general repairs is similar to the routine at San Bernardino, Cleburne and Albuquerque. The tender is uncoupled and the engine is sent to the erecting floor of the shop for dismantling. The wheels and running gear are loosened, wheels removed and heavy wooden blocks inserted. The locomotive is completely stripped and parts are cleaned in a lye vat. Pipes, pumps, cab, cylinders, domes and insulating lagging are removed, leaving the bare boiler and firebox resting on the frame. The boiler and frame are sand blasted and the frame removed. If defective, the latter is sent to the blacksmith shop where breaks are welded. Each part removed is marked with the engine's number and sent to the machine shop for inspection, repair or rejection.

After removal by acetylene torch, flues are placed in a tiimbling machine. This machine rolls the flues together until water scale is knocked off. Most of flues are found serviceable. Their damaged ends are cut off and new ends welded on and shaped for re-application to the boiler. A water pressure test, greater than actual working conditions, discloses possible leaks and weaknesses. Stayholts and radials are removed from the firebox when necessary and a new firebox shaped under huge rollers from 3/8 inch steel sections, drilled for staybolts, is riveted to both flue and door sheet. Defective boiler sections are replaced by new courses of heavy plate steel. On oil-burning locomotives, the oil tank is steamed to remove oil fumes to work on inside. Cistern, tank and tank frame are taken off the trucks which are overhauled. The fuel tank and water reservoir are checked for leaks.

Large wheel lathes true up the tires of the driving wheels, each tire in the set of six, eight or ten being turned to the exact size of the others. On the quartering machine adjacent to the wheel lathes, crank pins for the driving rods are turned down to exact adjustment and counter-balances are checked. Main and side rods are magnetic particle tested for invisible fractures or faults—a process using magnetic current and a sensitized powder dusted lightly over the part. With the passing of the magnetic current through the metal, the powder gathers over cracks and fissures. All working parts of the locomotive are given this inspection. Defective parts are scrapped. Rods passing the magnetic particle test are checked for out-of-round taper. When evidence of wear is found, the rods go to the micro-grinder or milling machine and the eye is machined to a new size and fitted with a new brass bushing. Crank pins on the wheels are trued up and new brasses fitted. Out-of-round or sembly from the locomotive cab are cleaned, checked and repaired.

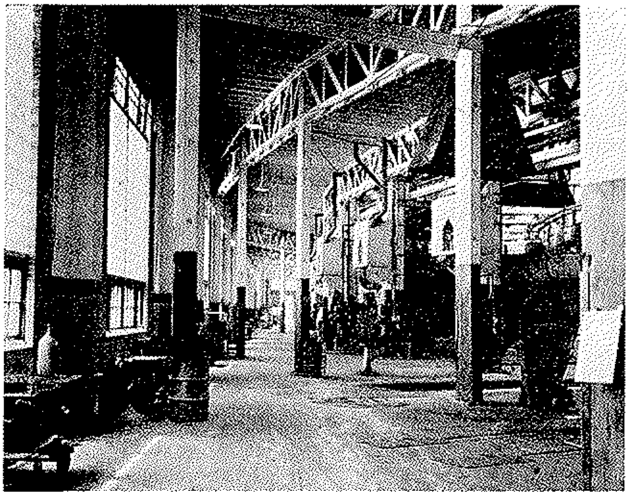
Inspectors closely observe the hundreds of working locomotive parts as they are reassembled. All the parts meet precision standards. The engine frame returns from the blacksmith shop, flues and superheater tubes from the flue shop. The firebox is lowered, staybolts and radial stays applied. Flues are installed. The boiler is given a hydrostatic test under twenty-five per cent



General view of yards and master mechanic's facilities at Amarillo, Tex. Each master mechanic is responsible for the daily requirements of motive power on his division and maintains locomotives assigned to his division, including steam, Diesel and motor cars.

worn cylinders are machined to a new size and fitted with new pistons and rings. New babbitt is applied on worn crossheads and then machined down to a predetermined size with exact precision. Driving wheel axles are placed in a big lathe and trued up. Driving boxes are rebrassed if necessary and bored to fit the axles. Parts for the valve motion undergo a careful inspection for wear and adjustment. Worn link blocks are huilt up with hrass welding. The valve link is ground to new size and the block machined down to fit within three-thousandths of an inch. Worn parts on the automatic stoker of coal-burning locomotives are built up by welding and fitted into new assemblies. The intricate parts of air pumps, valves, gauges, and the myriad as- greater than working pressure. Wheels, driving boxes, rods and boiler follow. When assembled, the locomotive is filled with fuel, water and essential stores. It is fired up and tested under steam, then moved to the slip track or taken on a trial run which shows its performance under working conditions and permits the newly fitted bearings to break in slowly. The trial trip usually is a slow, local run with a veteran engineer at the throttle. The slip track is a greased track near the shops where the engine's wheels "slip" over the track.

In major Santa Fe shops, the basic arts of machining — milling, grinding, turning, drilling and shaping or planing — are brought into fullest use in the general repairs program. All necessary machines for



interior view of a section of the reconstructed Santa Fe roundhouse at Argentine. Kan., one of the largest on the company's 13,000-mile system. In 1945 the roundhouse force here turned out 32,945 Steam locomotives. 9,758 Diesel-electric locomotives, and 602 gasoline powered motor oars, for a total of 43,305.

those operations and many others incidental to locomotive overhaul are in use. There is a giant 8,000-pound steam hammer in the Topeka shops used mainly for forging main and side rods. There are drilling, valve setting, press, slotter, screw, cutter, punch, shear and forging machines and numerous lathes, furnaces, pressure blowers, hammers, rollers, welders, hoists, and convenient hand cranes with chain hoists and great overhead cranes with capacities up to eighty tons. Safety is a constant theme.

In the Topeka shops' locomotive department is located the big tool room for the Santa Fe system. Here are heat-treated the tools for turning tires, reamers, lathe tools, shear blades, air-hammer tools, and a large quantity of flange contour tools. Helical milling cutters used for milling rods and valves and various locomotive materials are made, also locomotive taper reamers. Locomotive air gauges, steam gauges and hydraulic gauges for the entire system are repaired here, as well as air motors, all types, for pneumatic tools used on a large portion of the system lines.

All locomotive, passenger car and caboose springs for the system lines are assembled at Topeka shops. Springs are stripped, each leaf checked for defects, heat treated, assembled, and, in a locally devised hydraulic punch, straightener and leaf tampering machine, are brought to completion, dipped in a crater compound and tested in a 100,000-pound spring testing machine.

Some tires on Santa Fe locomotives (driving wheels) are turned by the time-saving Lidgerwood method. The latter method, first introduced by the Santa Fe in 1931, permits this task to be accomplished in eight hours. It is not necessary to drop the wheels. An ingenious device consisting of a steam winch, cable and anchorage, propels the locomotive over approximately 500 feet of track at a constant speed of ten to twenty feet per minute. Cutting and forming tools, in holders, bring the tires to required contours and diameters.

The passenger car department of the Topeka shops, manned by some 500 Santa Fe machinists, patternmakers, cabinetmakers, coach carpenters, upholsterers, painters, silver platers, welders, wood machinists, sand blast operators, coach truck repairmen, pipe fitters, coppersmiths, sheet metalworkers and others, repair, recondition and otherwise renew Santa Fe passenger, dining, baggage, express and mail cars. This shop is equipped to rebuild a complete car from trucks to upholstery. All classes of Santa Fe passenger equipment are given general classified repairs, electrical equipment is overhauled, and motors and miscellaneous electrical equipment and appliances for power driven units and for shop facilities are overhauled and rebuilt.

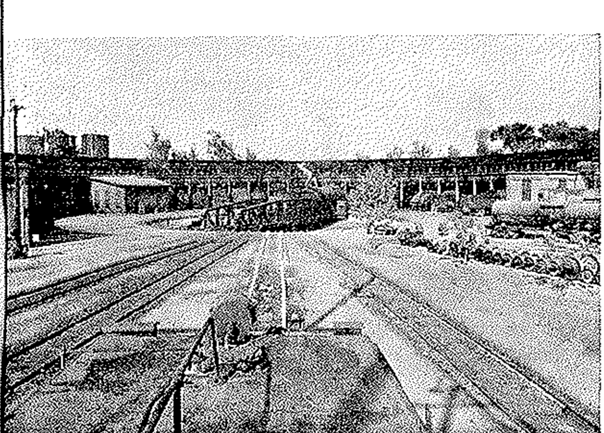
Santa Fe system pattern equipment is built and maintained here. Patternmaking is a difficult and exact art. For every casting there must be a pattern. Most Santa Fe patterns are made of northern white pine. Some of the finest cabinet work is done on the interior of Santa Fe dining and lounge cars. The cabinet shop refinishes or makes new all wood equipment on Santa Fe passenger and baggage cars, also mirrors. Battery boxes, section tool boxes, sign posts, and other wood fabrications are prepared and shipped throughout the system lines.

When received, a passenger car is first stripped of sash, chairs, seat frames, windows and similar equipment which is distributed to various departments for inspection, repair and replacement. After being sandblasted for repainting, car is placed on tripods and trucks are moved to the truck shop. Further stripping includes removing rusted-out side sheets or portions of the underframe. Wheels and axles go to wheel shop for turning and repairs to friction and roller bearings. All steel fabrications, exterior and interior, are shaped in the passenger car department. The pipe shop fabricates steam coils for heating purposes, also does air-conditioning repair work. The electrical department performs all shop electrical work including motors from shops, pumping plants and other facilities on Eastern and Western lines. Car generators are overhauled and general electrical repairs are made on all cars reaching the shop. Storage batteries are rebuilt, also are assembled and shipped throughout the system. Baggage cars carry the smallest batteries, dining and lounge cars carry the largest.

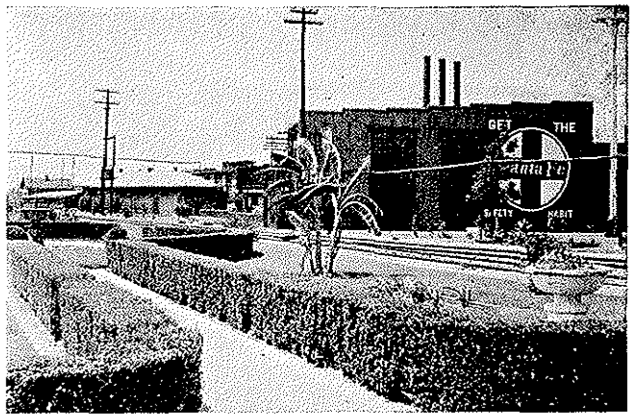
Dining-car kitchen, pantry and range equipment, steam tables, copper floors, table tops and other parts, go to the tin shop. The Topeka tin shop does galvanizing for the system and furnishes everything in tinware and tin lines including gutters, downspouts, skylights, fusee and torpedo boxes, stencils, flag boxes, oil cups, vegetable cans for dining cars, and numerous other articles prepared on shop order.

Locks used on Santa Fe passenger cars and by Fred Harvey are repaired at Topeka. Chair cars have an average of seven locks. Dining cars have as many as 140. Saws used on system lines are repaired and reset. Blocking for freight loading, construction of ladders and other millwork, all mirrors used throughout the system, as well as repairs to baggage platform trucks, shovels, forks and others tools, are handled.

All carpeting and linoleum cut and laid in Santa Fe passenger cars is a responsibility of the upholstering department which also renews all fabric material to lounge chairs, berth sections, coach seats, window drapes, and related work. The Santa Fe has close to 100 types of upholstery and twenty different colors in linoleum. Carpeting has been reduced to eight designs. Upholstery is virgin mohair and top grain cowhide; linoleum is best grade of cork; carpeting is best grade of Wilton. Cab seats and curtains for locomotives also are made.



General view of the 35-stall roundhouse at Bakersfield, Cal., looking west from engine supply house.



Mechanical department buildings and grounds at Temple, Tex.

Detailed rules govern the painting, cleaning, fumigating and sanitation of Santa Fe equipment. Most Santa Fe passenger equipment receives five interior paint colors. Some stainless steel cars receive as high as eighteen interior colors. In all, there are approximately 250 different interior colors, heavy and light, in Santa Fe passenger equipment, effort being made to have not more than ten cars of similar colors. In the case of stainless steel equipment, the total variety reaches 164 colors, with no more than five cars containing similar color combinations except chair cars where ten may have similar combinations. Shopping period of passenger cars has been lengthened due to improved procedure and kind of paint used, the paint holding up longer in that type of equipment and extending repainting periods to as long as ten years. Predominating exterior color is the familiar Pullman green which has been in use since the turn of the century and found to be the most durable and practical of all exterior passenger car colors. The Topeka shops maintain a log on all Santa Fe passenger cars from the day they entered service.

After the passenger car is painted it is sent to the trimming track where sash and doors and all necessary equipment are applied. War necessitated some redesigning of passenger cars, including the installation of sleeping quarters for train crews. Boxcars placed in passenger train mail service are equipped with steam train line and special trucks, wheels and axles. The steam train line on passenger trains provides hot water, heat and steam for air-conditioning. Other train lines are the signal line and brake pipe. Freight trains do not have a steam line. Heating is the vapor system, atmospheric pressure. With air-conditioning, a thermostatic control permits heat or cold as desired, regulated electrically according to car temperature. BY the use of fin type pipe (240 feet within car) steam radiation has been improved about four to one. Water in passenger cars flows by gravity and pressure the latter supplied by the air brake equipment.

The celebrated passenger service which the Santa Fe has long supplied this nation is dependent to a great extent on the superior type of equipment used and the care given the latter by the passenger car shops. Late equipment embodies more and more the colors and associations of the West which the Santa Fe always has incorporated in its passenger advertising and which Fred Harvey has blended into his dining and hotel facilities.

In the freight car department of Topeka shops, light and classified general repairs are made to Santa Fe freight equipment of all types except refrigerator cars. Long rows of freight cars line the repair and rebuilding tracks. Nearly eight billion pounds of carrying capacity are represented in the Santa Fe's 81,000 freight cars. The average freight car has a carrying capacity varying from 80,000 to 140,000 pounds, depending on the type of car and its age. About twenty-five per cent of Santa Fe boxcars are steel construction which has proven to he the best type of construction for freight service.

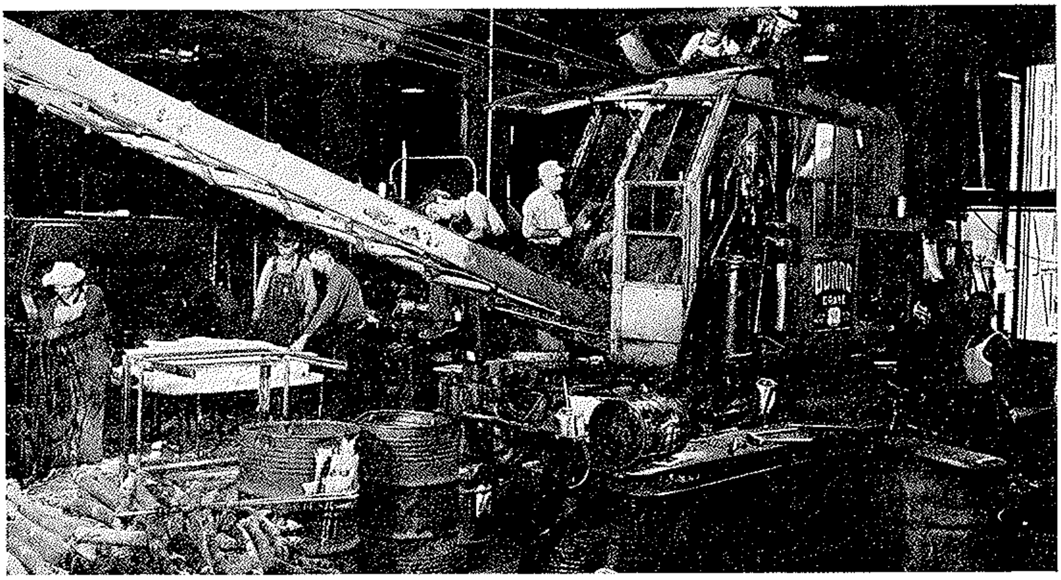
Each railway is responsible for the condition of all cars, foreign and owned, on its line and must give to all equal care as to inspection and lubrication. Foreign cars under load requiring repairs account owner's defects are repaired to a minimum necessary for the safety of the cars, their contents and railway trainmen. All procedures are governed by Association of American Railroads code of rules governing the condition of and repairs to freight and passenger cars on other than owner lines.

Body, floor and roof repairs run highest in freight car shop work, particularly on the older cars. In railway freight car building and repair, the use of pine for flooring and fir for roof, sheathing, lining, siding and post pillars predominates. Flat or cracked wheels, damaged trucks, faulty hrake rigging, draft gear damage and other causes bring the car to the shops where it is first placed on the stripping track: The trucks go to the truck repair shop, wheels to the wheel shop. Freight car wheels are of two types, iron and steel. The trend in recent years has been toward steel which can he turned. The iron wheel cannot be turned although it may be ground to a new size if practicable. Different sized wheels may be used in the same set of trucks, but each wheel in a pair must he uniform in size. With newly turned or replaced wheels, the trucks are reassembled. New or rebuilt parts replace those showing excess wear. Necessary welding or reinforcing is done. Car flooring, sheathing and roof are checked and renewed if necessary.

Cars which are given heavy repairs have the underframes repaired and made ready. The underframe is then sandblasted and prefabricated steel sides, ends and roof are applied. Car parts then are reamed and rivets applied. This is the "spot" system, the car moving from one location to the next as the work progresses. Side and end metal ladders, hrake steps, geared hand hrake, latitudinal running boards are applied; then safety appliances are riveted, side door track and side doors and other parts installed until car is completed. It is then switched to paint track (or to sand blast track if necessary) and is given two coats of the familiar mineral brown freight car paint. The application of each coat requires but fifteen minutes. Car is then stenciled with initial and number, as well as Santa Fe system map and other advertising slogans. In addition, the air date, packing date, light weight and load limit capacity are stenciled. A completely repaired car moves off the repair track each hour.

Light repairs to freight cars are done on the "rip" track, where wheels are changed, as well as couplers, draft gears, brake beams and other parts. Journal boxes are inspected, waste removed and replaced where packing date has expired. Air brakes are cleaned, oiled, adjusted, tested and stenciled—the K-2 each fifteen months, the A-B each thirty-six months.

Steel freight cars, including tank, box and auto cars, gondolas and others, are dismantled with the aid of overhead cranes. End doors and ends of steel boxcars are thus removed as well as heads and shells of tank cars. Tanlc cars are metal cylinders used to transport liquids in bulk. Some are glass lined. Gondolas are roofless cars with solid fioors or bottom doors, described variously as high side, low side, drop end, drop bottom, general purpose and convertible. Repairs must conform to the heavy use to which these cars are subjected.



Burro crane being repaired by the water service department in Topeka. This department performs a wide variety of work, in addition to making general and heavy repairs to all classes of work and roadway equipment—ditchers, pile drivers, ballast spreaders, track motor cars and many others—also miscellaneous shop work for the system lines.

Refrigerator cars are repaired in the Santa Fe's West Wichita shops. Refrigerator cars must bc properly insulated, able to withstand moisture, protected from the sun and outside atmospheric conditions including contamination from any cause. As a result, Santa Fe refrigerator department's bright orange colored cars, which transport meat and many other perishable products and a considerable portion of the Southwest's citrus, melon, lettuce, carrots and other crops, receive exacting overhaul. Wichita shops perform running repairs and complete overhaul where necessary to keep all possible refrigerator cars in service.

Thousands of bolts, nuts, studs and miscellaneous items are made in the Topeka shops. Salvage of usable materials involves many ingenious procedures. Boxcar steel ends are used for siding on mill type coal cars. Defective axles and many other parts are used in forgings. Broken asbestos insulating blocks are ground up and processed for re-use. Dirty journal packing is cleaned. Defective flues go into locomotive pilots. The list includes virtually each worn or defective part removed from the locomotive or car. Many parts are designed with extra weight or of extra size so that they can be machined for subsequent fittings. Relatively few parts are scrapped.

Topeka shops has a sizable stockpile of lumber which is air-dried and then placed in a dry kiln. The latter serves about fifty per cent of the Santa Fe's lines. Lumber usually is air cured for twelve months. The steam heated dry kiln subsequently brings it to a moisture content meeting Santa Fe specifications—eight per cent for siding, ten per cent for lining, twelve per cent for flooring, and many others. In the planing mill, a four-side planer planes the lumber to dimension or shape desired. Stockcar side sills have a four-planed surface; siding, lining and decking of stockcars or boxcars have one edge machined with a tongue, the opposite edge with a groove. A cut-off saw cuts to correct length. Lumber is gained or rabbitted and counterbored as desired then moved into the finished material storage huilding ready for application to cars. An air hrake room, waste and oil reclamation plant, brake beam and coupler department are other divisions of the Topeka freight car department.

The water service department maintains the shops' power generating plant and water pumping facilities which includes reservoir and all facilities for supplying and purifying water for the entire shops. Here are made general and heavy repairs to all classes of work and roadway equipment—ditchers, pile drivers, ballast spreaders, track motor cars and many others—also miscellaneous shop work for the system lines. All the rubber car hose for the system is tested and renovated, special shop order work is completed, pumps, portable lighting equipment, boilers, jacks, generators and kindred equipment including overhead and other cranes are repaired and installed.

The superintendent of shops has a clerical staff headed by a chief clerk who is responsible for the proper compilation and submission of all reports and statements regarding output of all power and equipment and materials; and the cost data pertaining thereto. The distribution of labor and material as prescribed by the Interstate Commerce Commission and Santa Fe accounting department rules, preparation of pay rolls, maintenance of seniority records in accordance with agreements in effect with the various labor organizations, and all statistics regarding the operation and maintenance of the entire plant under the jurisdiction of the superintendent of shops, are additional duties. Each mechanical superintendent likewise has accountants and other clerical assistants who handle similar data for the mechanical superitnendent's territory.

South of the Motive I'ower Building at Topeka shops is located the shops fire department and fire-fighting equipment in charge of a fire marshall and assistants including volunteers and numerous guards who constantly patrol the shop premises. The location permits two-minute access to the most distant point within the shop grounds. In line with the published ***fire rules*** all major Santa Fe shops have an elaborate system of alarms, roads, hydrants and sprinkler systems in the potentially dangerous locations such as the woodworking and paint departments. A constant water pressure of eighty pounds is raised to 120 pounds when an alarm is sounded. From 6:00 p.m. to 6:00 a.m. American watchman's time-detector system, with periodic wind-box reporting by guards, protects the shop premises.

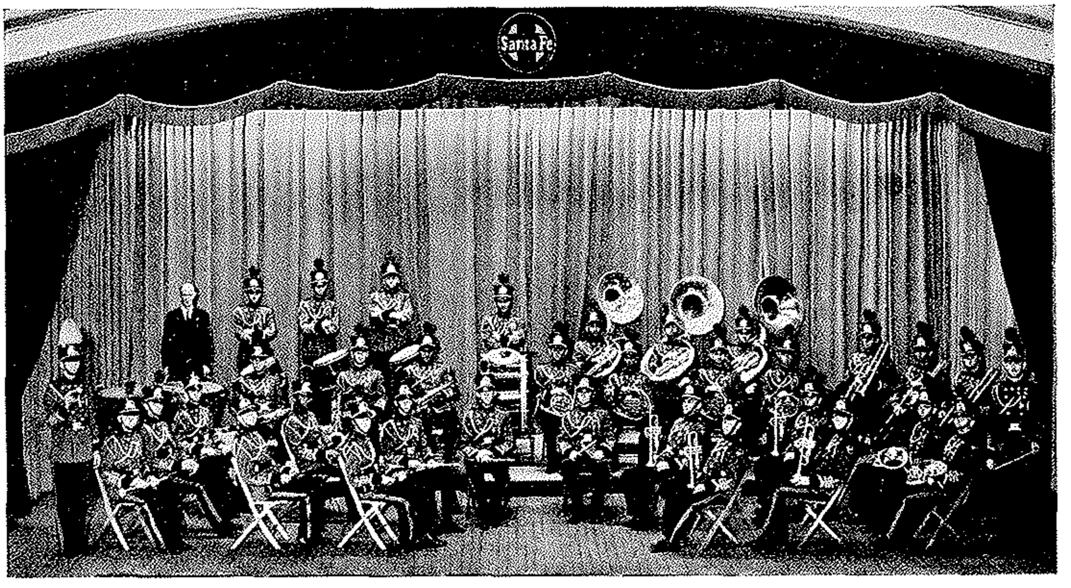
At Topeka shops, as well as other Santa Fe shops, each department is dependent on the other to maintain scheduled dates for locomotives, passenger and freight cars and other equipment to return to service. A great many forgings and other materials are required in the construction and repairs to freight and passenger equipment. These parts must be furnished by the forge and boiler shops on fixed dates; likewise, material must be obtained from the locomotive shops and water service division.

Winslow's famous Santa Fe All-Indian Band. This well known musical organization has been active 23 years providing regular concerts for home folk and traveling to various county fairs, conventions and festivals in many states to publicize Winslow and tho Santa Fe. Shown in center is O. L. *Gray*, general manager of thp Eastern Lines who was superintendent at Winslow from 1936 to 1941, during which time this picture was taken.

Completion of repairs to locomotives is dependent to a degree upon the prompt furnishing of cab appliances by the car department, also upholstered cab seats and backs and other essential parts. The superintendent of shops must supervise the scheduling of locomotives and cars through the repair shops insuring that maximum numbers are released each day. He must employ and allocate properly skilled workmen to the various departments, maintaining a balanced force throughout.

There are fifty-five foremen at Topeka shops (and a comparable number at San Bernardino, Albuquerque and Cleburne) under the direct supervision of a general foreman. Each foreman is in charge of a crew vital to the output of locomotives, passenger and freight cars, work equipment and miscellaneous parts, appliances and equipment made in the shop on order of the stores department for shipment to all parts of the Santa Fe system. Such material is not confined to the mechanical department but includes material essential to the efficient operation of the entire system.

Training in safety practices, as well as instilling in the minds of each member of the shops personnel the need for safety, is an important responsibility of the superintendent of shops who, as chairman of the shops' safety committee, conducts bimonthly meetings and never-ending safety campaigns. A shop safety supervisor attends all meetings and makes periodic inspection of the shops. Close co-operation between supervisory forces and the members of the safety committee is required and it is their joint responsibility to see that all safety rules are kept. Recommendations for revising, eliminating or inserting additional safety rules, is made by the committee. If approved by the chairman, the recommendation is submitted to the shop safety supervisor for any action he desires to take.



The Santa Fe Topeka Shops Band, since its organization in 1911, has participated in numerous Santa Fe events as well as system-wide civic functions.

Statistics, safety posters, and other literature supplied by the system safety deparement are sent to the various members of the committee for their information and dissemination to the personnel and for posting on bulletin boards. Data regarding all personal injuries is compiled by the superintendent of shops for transmittal to the shop safety supervisor and superintendent of safety.

The Santa Fe Topeka Shops Band, celebrated throughout the system, was founded in 1911. Since that year the band has participated in numerous Santa Fe events as well as system-wide civic functions. During the summer months, the band gives regular public concerts in Topeka. It actively participates in community affairs and its members have proven tireless in their efforts to maintain the band on the high plane instituted by its original members.

Mechanical Engineer

THE Santa Fe's mechanical engineer, H. H. Lanning, Motive Power Building, Topeka, supervises mechanical engineering details in relation to the maintenance, operation and improvement of existing steam and Diesel locomotives, the design and construction of new locomotives, the design and construction of floating equipment, and other special items in relation to those procedures. The mechanical engineer has an assistant and force of draftsmen and blue-printers skilled in locomotive specification and design.

When the Santa Fe orders new steam locomotives from the builders, specifications for each class or group of locomotives are compiled by the mechanical engineer and sets of drawings are furnished the builders. A representative of the mechanical engineer's office is stationed in the engineering department of the locomotive works during the engineering phases of the building program. As soon as construction of the locomotives is under way, a force of inspectors, reporting to the mechanical engineer, is stationed in the builder's shops to insure that drawings and specifications are complied with.

The above practice has been in effect on the Santa Fesince 1915. All new Santa Fe steam locomotives purchased since 1927 have been so entirely designed and specified by the Santa Fe that they may properly be regarded as exclusive Santa Fe products. Those locomotives include the Santa Fe's steam classes 2900, 3751, 3765 and 3776 (4-8-4 type), 3450 and 3460 (4-6-4 type), 4101 (2-8-4 type) and 5000 and 5011 (2-10-4 type).

The mechanical engineer's files contain approximately 8,000 drawings almost all of which apply to locomotives. Revisions are continually being made in those drawings to keep them up-to-date and to provide for improvements necessitated by service requirements. All inquiries and recommendations regarding locomotive design, construction, and maintenance requiring attention along engineering lines are cleared through the mechanical engineer's office; and all general instructions, specifications, drawings and related matters which are to be followed in the Santa Fe's locomotive shops

H. H. Lanning, mechanical engineer,. yith headquarters in the Motive Power Building, Topeka. Kan.

are issued from his office. He also edits the important steam and Diesel-electric locomotive and work equipment folios. Many inquiries pertaining to locomotives from other railways, as well as questionnaires from the Association of American Railroads and various governmental agencies are referred to the mechanical engineer for detailed handling.

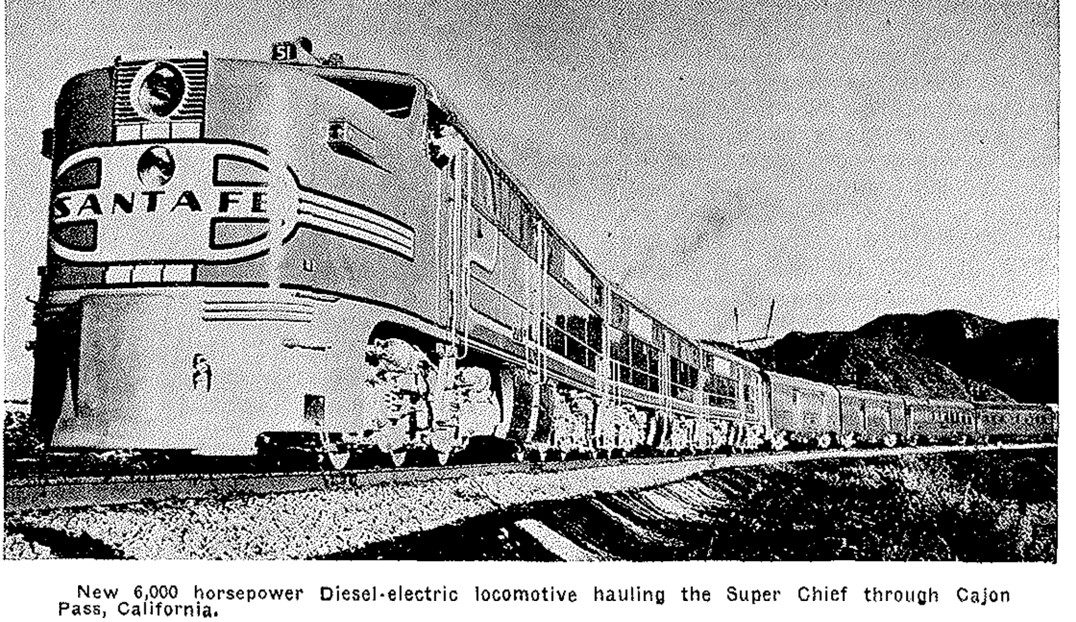
Some years ago, the mechanical engineer's office devised a systemwide practice whereby failures of all Santa Fe locomotive parts are reported and classified for study. The practice subsequently was extended to other Santa Fe departments. The system is based on a printed form (1263-Standard) upon which a sketch of the failed part is drawn and various items of pertinent information are recorded by shops and roundhouses where the failed parts are discovered and removed from the locomotives. The mechanical engineer studies each form submitted and if forms relating to any particular part are received in number, a complete analysis is made of the failures and remedial action is taken.

Various forms and reports are required by the Interstate Commerce Commission covering the design, construction and main-

Diesel-electric, 4,000 horsepower, two unit locomotive which hauls the Super Chief between Chicago and Los Angeles, 2,227 miles.

tenance of steam and Diesel locomotives. Periodic inspections are made by I.C.C. inspectors. All practices in relation to Santa Fe motive power are designed to meet I.C.C. requirements and the high standards established by the Santa Fe. There are as many as 25,000 parts in some Santa Fe locomotives. Each part is carefully adapted to its individual purpose. All likewise conform with or are equal to the specifications of the Association of American Railroads. The Santa Fe's locomotive folio contains Santa Fe standards for repair and maintenance of coal and oil burning steam locomotives; also data on the dismantling and replacing of parts.

Santa Fe mechanical engineers have played an important role in the development of modern railway motive power. It was only after persistent labor that the Santa Fe successfully utilized four-wheel trailer trucks (1919). There was considerable speculation regarding the now proven adaptability of the 300-pound radial stay boiler introduced by the Santa Fe in 1930. We have noted those and the many other Santa Fe contributions to railway motive power.

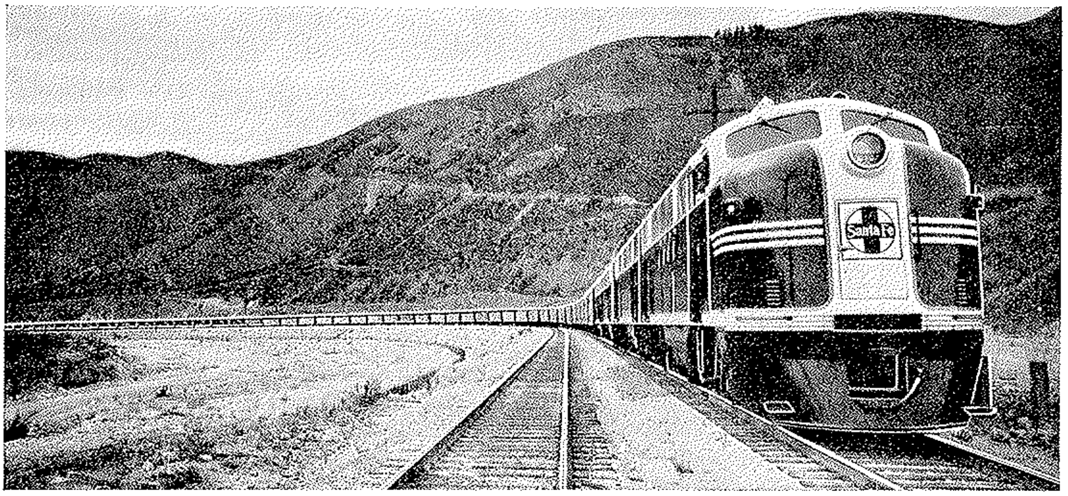


New 6,000 horsepower Diesel-electric locomotive hauling the Super Chief through Cajon Pass, California.

The Santa Fe operates more than 1,500 steam locomotives in passenger, freight and switching service, 80 Diesel-electric freight locomotives, 144 Diesel-electric switch locomotives, and fifteen Diesel-electric passenger locomotives. A resume of that power discloses many interesting items of a practical as well as of a historical nature.

Steam locomotives are identified by the wheel arrangements. The 4-8-4 (ooOOOOoo) type popular on the Santa Fe has four small wheels in front (pony trucks), four sets of driving wheels, and four small wheels in the rear (trailer trucks). The 4-8-4 type locomotive now in use on the Santa Fe definitely is a Santa Fe product. In 1926, outline drawings and specifications were made by the Santa Fe for the construction of an experimental 4-8-4 type. The design was later worked out in detail in collaboration with engineers of the Baldwin Locomotive Works and an experimental locomotive No. 3751 was built and delivered to the Santa Fe in 1927. Thirteen additional 4-8-4's were delivered during 1928 and 1929. In 1936, the design was greatly improved, the 4-8-4's in service were rebuilt and orders were placed for eleven others which were delivered in 1938. The latter's performance was so outstanding that ten additional ones were received in 1941 and another lot of thirty in 1944. The latter group, Nos. 2900 to 2929, inclusive, are being used in freight service between Kansas City and Clovis where tonnage and speed restrictions are quite exacting. The balance of the Santa Fe's 4-8-4's are operating in through passenger runs between Kansas City and Los Angeles. The rated tractive force of this type locomotive is 66,000 pounds.

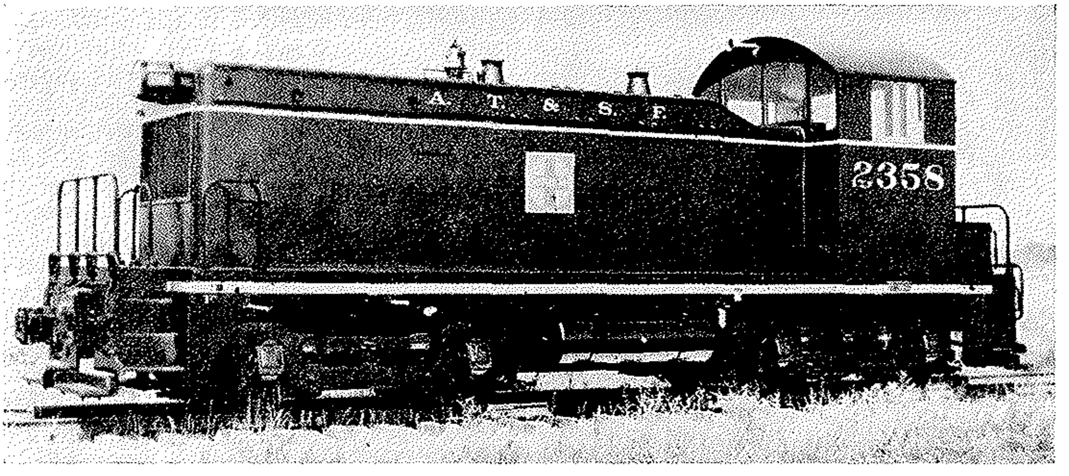
Steam type locomotives 4-6-4 consist of ten 3450 class locomotives which were purchased from the Baldwin Locomotive Works in 1927 and are used in passenger service between Argentine, La Junta, Clovis and Galveston, and six 3460 class locomotives which were built by the Baldwin Locomotive Works in 1937 and are in operation between Chicago and La Junta, being assigned to The Chief and mail trains 7 and 8. The rated tractive force is 43,300 for the 3450 class and 49,300 for the 3460 class.



Diesel-electric locomotive, 5,400 horsepower, designed and built far freight service on the Santa Fe.

The Santa Fe 2-10-2 type locomotive was designed in 1903 to suit the peculiar requirements of Santa Fe mountainous districts. For a number of years, the Santa Fe was the only railway owning and operating locomotives of this type, although use of the type was later extended to many other roads. The Santa Fe has at various times owned 362 locomotives of this type; it now owns 287 of which 140 are used in main line freight and helper service, the remainder in switch and other secondary classes of service. The last Santa Fe 2-10-2 was received in 1927. Maximum tractive effort is 85,360 pounds.

Locomotives of the Santa Fe type are being superseded in main line service by the Santa Fe's 5,400-h.p. Diesel-electric freight locomotives, four units; also on certain territories by steam locomotives of the 2-10-4 type, represented by classes 5000, 5001 and 5011. Thirty-six of these classes are in service. The 2-10-4 is a Santa Fe development although credit for originating this type sometimes is given to the Texas & Pacific Railway for a group of locomotives of the same wheel arrangements, commonly referred to as the Texas type, which were built and delivered in 1926 and 1927. Insofar as can be developed, Santa Fe engine 3829, built in 1919, for the purpose of developing the possibilities of the 4-wheel trailer truck as well as the 2-10-4 type wheel arrangement, was the first of the latter design. A second experimental locomotive of this type, No. 5000, was built in 1930. The two experimental locomotives were used by Santa Fe engineers as the basis for the modern 2-10-4 type locomotives of classes 5001 and 5011. Rated tractive force of the latter classes is 93,000 pounds.



Diesel switch locomotive No. 2358, typical of the 123 Diesel switchers in service on the Santa Fe.

The Santa Fe has thirty-one locomotives of the Atlantic 4-4-2 type used only on light branch-line passenger- and mixed train service and to protect a few lightweight high-speed main line trains. The first Atlantic type locomotive owned by the Santa Fe, No. 40, built in 1887, included in its design a number of unusual features which did not work out so well in everyday service. The locomotive was rebuilt into an 8-wheeler and as such remained in service until 1925. No further attempts to utilize locomotives of the Atlantic type were made until 1903 when four locomotives of this type were built and placed in service. The last locomotives of the Atlantic type purchased by the Santa Fe were the 1480 class received in 1910. The Santa Fe has owned 172 locomotives of this type, the maximum tractive force of which is 29,400 pounds. Locomotives of the Pacific type ultimately succeeded the Atlantic type in level territory passenger service.

The Santa Fe has 189 passenger locomotives of the Pacific 4-6-2 type used in main line service on the prairie districts where they are gradually giving way to more powerful locomotives of the 4-6-4 and 4-8-4 types. The latter were originally purchased for mountain territories but are now being used on the level districts by reason of extended locomotive runs. The earliest Pacifics received on the Santa Fe were the 1200 class delivered in 1903. The last were of the 3400 class, Nos. 3440 to 3449, delivered in 1924. The first locomotives of this type were used principally in passenger service on heavy grades, but their use was later extended to the prairie districts as the trains became too heavy for the Atlantic type locomotives. The maximum tractive power of the Santa Fe's Pacific type locomotives is 42,200 pounds. They were directly superseded on the mountain territories by locomotives of the Mountain type, 3700 class.

The first locomotives of the Mountain 4-8-2 type were delivered to the Santa Fe in 1918 for heavy passenger service on mountain territory. The last was received in 1924. A total of fifty-one were acquired and all are still in service. These locomotives have been largely superseded in passenger service by locomotives of the 4-8-4 type and indications are that all of the Mountain type will soon pass into fast freight service on the prairie districts where some of them are giving a very good performance. Rated tractive power of the

Santa Fe's Mountain type locomotive is 56,800 pounds.

During the period extending from 1901 to 1907, the Santa Fe received 233 locomotives of the Prairie or 2-6-2 type. Four others of this type were produced by the reconstruction of Pacific type locomotives in 1929. In all, 198 Prairie 2-6-2's are now in Santa Fe service. In the beginning, this locomotive was considered a dual purpose locomotive possessing sufficient tractive power (43,200 pounds) to make a creditable showing in freight service and necessary speed to handle passenger trains. Actual experience proved these locomotives unsatisfactory for passenger service, but well adapted to freight service on the prairie districts. At the present time the usefulness of this type is limited to branch line freight and mixed freight service and main line work trains of light consist. They have been superseded by the Mikado type in heavy main line freight service on the prairie districts. In passenger service they have been superseded on the prairie districts by locomotives of the Atlantic type and in mountainous districts by the Pacific type.

The Santa Fe has 304 locomotives of the Mikado 2-8-2 type, the first of which were received in 1902 and the last in 1926, all in service. Originally constructed for heavy mountain service, this design was found to be well adapted to the lighter grades of the prairies. A few of the older locomotives of this type are now used in local freight and switch service. The remainder are per. forming main line freight service. The minimum tractive effort of locomotives of this type is 63,000 pounds. A later development of the Mikado type, the 2-8-4, is represented by the 4101 class. The Santa Fe has fifteen of the Iattcr all of which were built in 1.927 to suit the particular requirements of the Missouri Division. Their tractive force is 69,400 pounds.

During the war, when we were in need of additional power to handle the excessive amount of traffic offered, we purchased seven 2-8-4 locomotives from the B. & M. Railroad, these engines having a tractive effort of 69,400 pounds.

The Santa Fe owns and operates 166 locomotives of the Consolidation 2-8-0 type. It also is preserving as a relic locomotive No. 2414 of this type which mas built in 1880 for heavy mountain service on Raton Pass. All Santa Fe locomotives of the Consolidation type are quite old, the newest being received in 1913. When built, all were considered heavy freight power although the highest tractive force developed by any of them is 52,800 pounds. Practically all locomotives of this type now are in switching service.

The Mogul type 2-6-0, considered obsolete on the Santa Fe, is used entirely in local freight or mixed service on branch lines. The Santa Fe has only six locomotives of this type, acquired in the purchase of other lines in Oklahoma and Texas. They will be retired when in need of extensive repairs.

The Decapod 2-10-0 type has never been used to any appreciable extent on the Santa Fe. Three locomotives of the 2-10-0 wheel arrangement were received from builders in 1902 but all of them have since been scrapped. Six additional Decapod 2-10-0's were acquired in the purchase of the Orient Railway and are still used in that territory. Their rated tractive effort is 60,000 pounds.

The Santa Fe's experience with locomotives of the Mallet or Articulated type has not been satisfactory. At one time the Santa Fe owned thirty-three Mallets of various sizes and wheel arrangements. All of them were scrapped or rebuilt into single wheel-base locomotives prior to 1933. During late years, Mallet locomotives Nos. 1700 to 1797, inclusive, were purchased second-hand to satisfy an urgent need for additional power to handle war traffic. It is probable that the latter will not remain in service much longer.

The Santa Fe at present has 326 steam locomotives assigned to switching service on the system lines. Of these, eighty-one were designed and built especially for that class of service; 108 were road locomotives which have been more or less modified to adapt them to switch service; 137 were designed and built for road service and are being used as switch engines with no essential change having been made in the construction of the locomotives. No new steam locomotives have been built for the Santa Fe for switching service since 1912.

Steam power built up the Santa Fe. One can not minimize the huge task which Santa Fe coal and oil burning steam locomotives have performed through many decades. The fact that some steam locomotives are rated as old is not literally true as periodic overhaul and replacing of parts, as well as the addition to such equipment of serviceable innovations, enable each locomotive, regardless of delivery date, to perform those essentially important Santa Fe functions best suited to their individual capabilities.

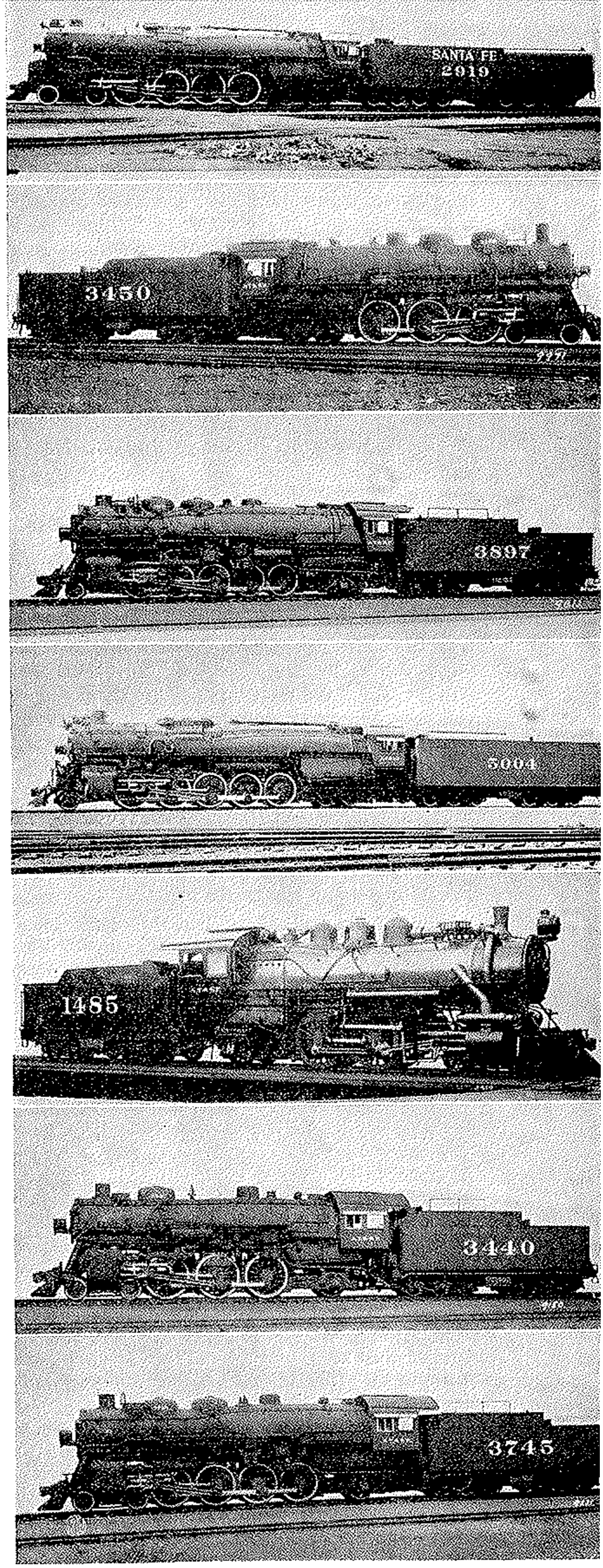
The performance of the Santa Fe 2-10-4's, recently delivered, is worthy of note. Locomotive 5011 of this class, tested eastward over Cardy Hill between Elmer and Cardy on the Missouri Division, a continuous upgrade for almost five miles, the greater portion of which has an incline of approximately 0.8 per cent, with 5,006 tons (89 cars) approached the incline at a speed of 57 miles per hour. At the end of the five-mile grade the speed was 22 miles per hour. On the same grade with 5,441 tons (94 cars), the 2-10-4 approached the grade at a speed of 56 miles per hour reaching the end with a recorded speed of 18 miles per hour. Those performances were 20 per cent better than the estimated capacity on such an incline.

Santa Fe Diesel-Electric Locomotives

The Santa Fe was the first railway to use Diesel power in all branches of service — freight, passenger and switching. It pioneered the operation of large groups of passenger, freight and switch Diesel-electric locomotives, having placed in service 239 engines since 1935. The Santa Fc, in many respects, has served as a proving-ground and a school for Diesel-electric operation on railways of the United States and some foreign countries.

Santa Fe Diesel-electric passenger locomotives operate between Chicago and the Pacific Coast and on numerous interstate and local runs. Santa Fe Diesel-electric freight locomotives operate between Winslow and Barstow, Barstow and Bakersfield, Barstow and San Bernardino, Chicago and Argentine, Argentine and Winslow, and Argentine and Cleburne. Diesel-electric switching operations are spread throughout the system lines.

BY generating dependable and economical power in comparatively lightweight, serviceable units, the modern Diesel engine has contributed much toward the comfort of train travel and the facility of freight movements. Diesel operations on the Santa Fe are subjected to various operating conditions — maximum grades, extreme heat



Various classes of steam locomotives now in service on the Santa Fe are pictured here and on the second following page. Steam locomotives are identified by the wheel arrangement. The 4-8-4 type popular on the Santa Fe has four small wheels in front (pony trucks), four sets of driving wheels, and four small wheels in the rear (trailer trucks); the 2-10-2 type has two small wheels in front, five sets of driving wheels, and two small wheels in the rear, etc. All are described in the accompanying article.

and cold and volume traffic. The Dieselizing of Santa Fe freight service between Winslow and Barstow is a notable wartime achievement. That territory, 460 miles in length, embraces long 1.42 per cent ascending grades and one stretch of 1.8 per cent ascending grade. It encompasses the Mojave Desert and has extremes of temperature. The eighty-two miles between Barstow and San Bernardino (via Cajon Pass), and the 141 miles between Barstow and Bakersfield (over the Tehachapis). mostly Dieselized. have long stretches-of 2.2 per cent ascending grade.

The Santa Fe's fleet of Diesel-electric passenger locomotives, silver, red and yellow, its Diesel-electric freight units, vermilion, Santa Fe dark blue, yellow and bronze, highlighted the modern era of railway operation which saw the introduction of air-conditioning and stainless steel streamlining. Diesel power supplied a long felt need for safe, economical continuous operation at high speeds for long distances. Among the favorable operating disclosures was the improved handling of the locomotive made possible by uniform tractive effort at the start and ease of control. Tho 5,400-h.p. Disel-electric freight locomotive, four units, has a tractive force of 230,975 pounds.

The log of Diesel-electric locomotive acquisition by the Santa Fe follows:

1936, February. First Diesel-electric loco. motive delivered to the Santa Fe, a 600-h.p. switcher, American Locomotive Company, was placed in service in Chicago yards for observation.

1935, August. First Diesel-electric passenger locomotive received, a 3,600-h.p. two unit, Electro-Motive Corporation, was placed in service May 12, 1936, between Chicago and Los Angeles on the Super Chief after various test runs.

1936, March. A 600-h.p. switch locomotive, Electro-Motive Corporation, was received and placed in service at Chicago yards for observation.

1936. During this year, one 1,800-h.p. passenger unit similar to the two units which were placed in service in 1936, was leased from Electro-Motive Corporation for use as a relief unit on Super Chief. It was also used at times on other trains between Chicago and Kansas City.

1937, July. Two 600-h.p. switchers, American Locomotive Company, and one 600-h.p. switcher, Baldwin Locomotive Company, were placed En service at Chicago. Three 600-h.p. switchers, Electro-Motive Corporation, were received and placed in service at Los Angeles, Galveston and Chicago.

1937, September. Three 900-h.p. switchers, Electro-Motive Corporation, were placed in service at Chicago.

1937, May. A 3,600-h.p. two unit passenger locomotive of improved design, Electro-Motive Corporation, was placed in service and operated on the Super Chief in place of the former locomotive which was then utilized on miscellaneous trains and also used as a relief locomotive for Super Chief when needed.

1938, February 22. Another Super Chief was placed in service and a two unit 3,600-h.p. locomotive assigned to the run.

1938, February 22. The El Capitans were placed in service, making two round trips per week between Chicago and Los Angeles. Two 1,800-h.p. locomotives were assigned to these runs.

1938, March 23. The San Diegan was placed in service between Los Angeles and San Diego, making two round trips daily. One 1,800-h.p. unit was assigned to this service.

1938, April 17. The Kansas Cityan and Chicagoan trains were placed in service operating between Chicago and Wichita, each train making a one-way trip daily between those two points. One 1,800-h.p. locomotive was assigned to each train.

1938, July 1. The Golden Gate trains were placed in service between Bakersfield and Oakland, making two round trips daily. Two 1,800-h.p. locomotives each made a round trip daily.

1939, August. A two-unit 4,000-h.p. passenger locomotive of improved design, Electro-Motive Corporation, was placed in service, tested and used on various Santa Fe trains.

1939. During this year, twelve 1,000-h.p. switchers, American Locomotive Company, thirteen 1,000-h.p. switchers, Electro-Motive Corporation, and six 1,000-h.p. switchers, Baldwin Locomotive Company, mere placed in service at various points throughout the system lines. The Santa Fe now had a total of forty switchers in service.

1940, January. The Tulsan was placed in service between Kansas City and Tulsa, one round trip daily. An 1,800-h.p. locomotive was assigned.

1940. During this year, two 4,000-h.p. passenger locomotives, Electro-Motive Corporation, were placed in service, and Diesel locomotives were used on various passenger runs between Chicago and LaJunta. Additional units also were used on Super Chief, El Capitan, Kansas Citsan and San Dieaan runs when it was desired to handle largertrains.

1940, Decemher. The first four-unit, 5,400-h.p. Diesel-electric freight locomotive, Electro-Motive Corporation, was delivered to the Santa Fe and placed in service. This history-making event was preceded by exhaustive tests conducted by the Santa Fe's test department with this locomotive, received for test purposes on January 2, 1940.

1941, February. The first 44-ton Diesel-electric switch locomotive, Whitcomb Locomotive Company, was received and placed in service on the Santa Fe.

1941, March. A 44-ton smitcher, Davenport Locomotive Company, was received and placed in service. These 44-ton switchers were tested at varions places over the entire Santa Fe system in order to determine their merits.

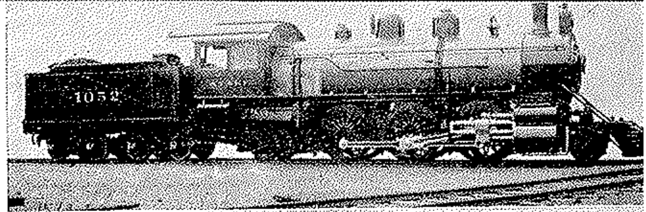
1941. During the year a 1,000-h.p. switch locomotive, Baldwin Locomotive Company, was placed in service. Three 2,000-h.p. passenger locomotives, Electro-Motive Corporation, were received. Two 2,000-h.p. passenger units, American Locomotive Company, were received and replaced locomotives on the Super Chief runs. Four 5,400-h.p. freight locomotives, Electro-Motive Corporation, were received and after being used in various runs were placed in service between Argentine and Belen with maintenance being done at Argentine, Kan.

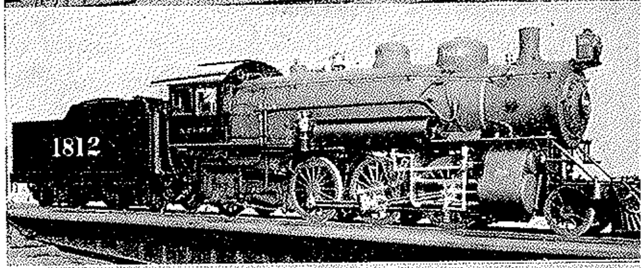
1942. During this year, two 44-ton switchers, General Electric Company, one 1,000-h.p. switcher, Baldwin Locomotive Company, and five 1,000-h.p. switehers, American Loconiotive Company, were placed in service at varions points on the system lines. The Santa Fe now had a total of fifty-one switchers. During the year, eleven four-unit 5,400-h.p. freight locomotives, Electro-Motive Corporation, were placed in service, operating west out of Winslow to Barstow, also to San Bernardino and Bakersfield. Maintenance was handled at Winslow.

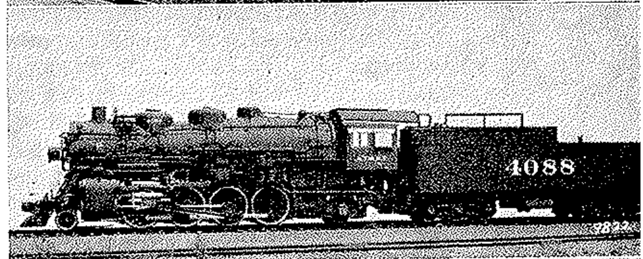
1943. During the year, five 44-ton switchers, General Electric Company, nineteen 1,000-h.p. switchers, Baldwin Locomotive Company, sixteen 1,000-h.p. switchers, American Locomotive Company, and two 1,000-h.p. switchers, Electro-Motive Corporation, were placed in service. During the year, sixteen four-unit 5,400-h.p. freight locomotives were placed in service west out of Winslow. The Santa Fe now had thirty-two 5,400-h.p. freight locomotives and ninety-three switchers in service.

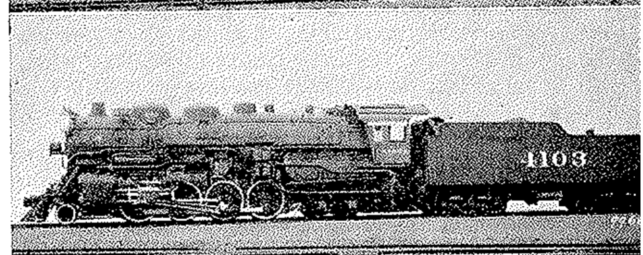
1944. During the year, one 44-ton switcher, General Electric Company, two 600-h.p. switchers, American Locomotive Company, twenty-one 1,000-h.p. switchers, Baldwin Locomotive Company, and five 1,000-h.p. switchers, American Locomotive Company, were placed in service at various points on the Santa Fe, a grand total of 123 switchers in service. Additional 5,400-h.p. freight locomotives were placed in service west out of Winslow, which, with orders to be filled and additional orders placed in December for this same type of freight equipment, gave the Santa Fe a fleet of eighty 5,400-h.p. freight locomotives—by far the largest fleet in service on any railway.

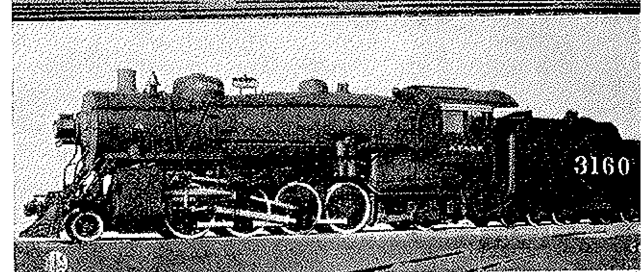
Santa Fe Diesel-electric equipment, men and methods, have changed considerably since the Santa Fe began its Diesel program in 1935. The first Diesel-electric pas-

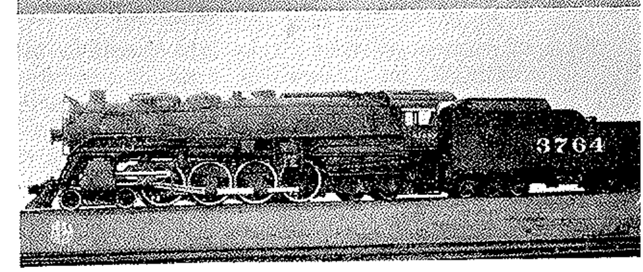












senger locomotive had four-wheel trucks which created excessive rail stress and had poor riding qualities. The radiator cooling air passed through the engine room causing rain, snow and dirt to enter. Steam generators did not have sufficient capacity to serve the train and were difficult to maintain. Engine lubricating oil pumps did not have sufficient capacity to maintain desired oil pressure for desert operation and there was insufficient radiator capacity to properly cool the engines.

Those deficiencies prompted Santa Fe engineers to design a six-wheel truck to replace the four-wheel truck. Cooling air ducts were installed to confine the air and keep water and dirt out of the engine room. Larger steam generators were installed. Booster lubricating oil pumps were applied and additional radiating capacity was installed. Those changes were so satisfactory they were incorporated by the locomotive builders on new locomotives which followed. There is a striking parallel in those endeavors to the long labors of Santa Fe mechanical department engineers in the task of perfecting Santa Fe steam locomotives.

Diesel - electric passenger locomotives originally were designed for maximum speeds of 117 miles per hour. That has been deemed unnecessary, however, and they now are designed for maximum speed of 100 miles per hour. The horsepower requirements of Diesel passenger locomotives fluctuates due to the size of the trains handled and the schedules it is found desirable to maintain.

Considerable experience with Diesel-electric locomotives had been gained prior to the building of the Santa Fe's first Diesel-electric freight locomotive. The latter was tested extensively on the Santa Fe's transcontinental lines and was found to be especially adapted to mountainous and desert operation, being able to operate long distances without frequent water and fuel stops, handling and starting trains on heavy grades very satisfactorily. During the test period it was indicated that the incorporation of an electric brake would eliminate damage to cars also stops for cooling of wheels. Such a brake was specified by Santa Fe engineers for new locomotives. It also was apparent that the automatic transition was not desirable for freight operation and new locomotives were designed for manual control. The first two 5,400-h.p. Diesel-electric freight locomotives placed in Santa Fe service were geared for eighty miles per hour maximum speed. The operation of these locomotives developed that sixty-five miles per hour maximum speed was more suitable for freight service. The first five 5,400-h.p. Diesel-electric locomotives had fifteen and twenty-five miles per hour two-stage dynamic brakes, but a more flexible electric brake was needed and all locomotives thereafter were constructed accordingly.

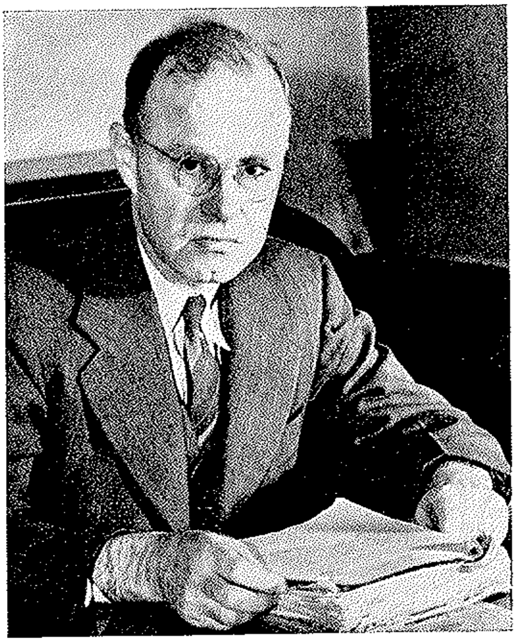
Each unit of the 5,400-h.p. Diesel-electric freight locomotive houses a 1,350-h.p. V-type Diesel engine, 2-cycle, with 16 cylinders, 8%-inch bore and 10-inch stroke. Air for combustion of fuel is furnished by especially designed high-speed blowers. Each Diesel engine drives one large electric generator which furnishes power to rotate electric motors, four of which are connected individually to four pairs of power wheels. One or two units can be removed from service to reduce the horsepower of the locomotive to 4,050-h.p. or 2,700-h.p. as desired, providing economy and flexibility in the matter of freight tonnage to be handled, and convenience in the matter of repairs to individual units. Until recently, the Diesel-electric freight locomotives consisted of one cab in the front end of the lead unit. Experience indicated that a cab unit at each end of the locomotive was necessary as it would give more flexibility to operation by not having to turn the locomotive at terminals; also wear on wheels and traction motor gears would be equalized.

With Diesel-electric switchers, all the weight of the switcher is carried on the driving wheels, with uniform torque exerted by an electric motor at each driving axle, giving the most effective return from the locomotive weight and producing high starting tractive effort. Economies having to do with availability, flexibility, efficiency, safety, fuel and water consumption, maintenance and other items, have contributed to the success of the Diesel-electric switcher.

The original 600-h.p. switcher was found too small for heavy switching. That brought about the construction of the 1,000-h.p. switchers (tractive force 61,550 pounds), able to handle practically all switching operations. The need for a small locomotive for industrial and light switching service was supplied by the 44-ton Diesel-electric switcher (tractive force 22,025 to 22,200 pounds), which is particularly adapted to that work. The eleven 44-ton switchers in Santa Fe service have turned in a fine performance.

Engineer Car Construction

THE car construction section of the Santa Fe mechanical department under the jurisdiction of M. R. Buck, engineer car construction, headquarters at Topeka, is responsible for the laying out



M. R. Buck, engineer of car construction, whose headquarters are in Topeka, Kan.

and construction of new Santa Fe passenger and freight cars as well as new work equipment required to meet Santa Fe traffic demands. After the design of car has been selected that department proceeds with calculations providing for proper physical characteristics of the new equipment needed to replace equipment destroyed or retired. The engineer car construction also checks into the changes necessary in existing equipment to meet traffic demands, which is accomplished by further developing Santa Fe owned improved features or the addition of various improvements placed on the market by railway supply houses.

The elimination of maintenance costs, breakdown hazards, and traffic delays, are prime reasons why a railway must eonsider at length the merits of the car equipment it designs or acquires in relation to the services such equipment will he required to supply; and all factors concerning depreciation, wear and tear, and facility of upkeep.

The engineer car construction's staff consists of an assistant to engineer car construction, chief clerk, chief draftsman, lead inspector, specialized clerks, draftsmen and inspectors. The inspectors are stationed at builders' plants where new Santa Fe cars are constructed, determining first-hand that Santa Fe cars are constructed in line with specifications.

The trend, which is recognized as a necessity in future railway operations, is toward lighter cars both passenger and freight. The Santa Fe's 1,435 passenger cars are of both heavyweight or conventional and lightweight design. Lightweight equipment is built of special alloy and aluminum structure instead of open hearth steel, shapes and flats, thereby reducing the per car light weight and the total tonnage of an average passenger train of fourteen cars. Such weight reduction does not reduce the carrying capacity of the train or cars. Passenger cars in service on the Santa Fe include the following types:

Baggage	Lounge
Cafe Observation	Lunch counter dining
Chair	Combination coach and mail
Coach	Mail or postal
Club	Parlor
Sleeping	Smoking
Dining	
Horse express	

Unlike freight cars, passenger cars do not experience a great deal of interchange between the railways. As a result, there is considerable individuality incorporated in the various passenger cars of the railways. Only a few Association of American Railroads' standards or recommended practices have to be considered. These concern couplers, draft gears, buffers, various safety appliances, hand brakes, side and end handholds, uncoupling levers, sill steps, side-door steps and others. The various Interstate Commerce Commission rules and regulations and U. S. Safety Appliance Acts apnlicable to railway cars in general—brakes, trucks, handholds and other features—must be observed.

The more than 81,000 freight cars owned by the Santa Fe, all of which play an important part in the freight traffic of this nation, include the following:

Air dump	Ballast
Caboose	Flat
Refrigerator	Ice
Tank	Box
Automobile	Gondola
Drover	Stock
Logging	

All freight revenue-carrying cars in interchange service on America's railways are designed according to certain fundamentals which experience has proven to be most practicable. Those fundamentals concern dimensions of particular types of cars, inside and outside, height above rail, various clearances, ratio of unit stress to end load, axles, trucks and other features. All revenue freight cars used in interchange service are slenciled to show the nominal capacity, the light weight and the load limit. The size of the axles determines the allowable weight on the rails. The light weight subtracted from the latter discloses the load limit. The latter includes blocking, bracing and racks in addition to the loaded commodity.

When Santa Fe freight cars reach a certain age, a repair limit (cost of repairs) is established in conjunction with a theoretical depreciation system which covers the life of the average freight car. That Prohibits shop forces from expending time and money on cars which have served their purpose, having reached obsolescence or a state of deterioration through heavy service. When Santa Fe inspectors find cars need excessive repairs, they request authority from the engineer car construction to dismantle them. If authority is granted, the Car is torn down and eliminated from "live" car accounting records. Such dismantling often releases serviceable items — truck and brake rigging and other parts — for use on other cars.

In the maintenance of its vast facilities, the Santa Fe must utilize many types of cars in its private service — living quarters for track and other crews, water, fuel and other supply cars. It is a function of the engineer car construction to create or otherwise provide this work equipment, totaling some 6,000 cars, which includes the following types:

Bunk	Water	Tool
Storage	Rip-rap	Fuel
Kitchen	Foreman	Track
Shop	Cinder	Material
Dining	Idler	Commissary
Living	Wheel	Recreation

Workmen at Topeka shops repairing doors in roofs of grain or cement hopper cars. A sizeable program is under way to modernize and otherwise improve various classes of Santa Fe freight equipment.

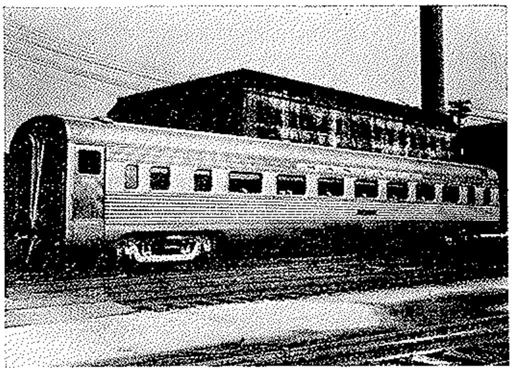
Standard wrecking outfits are designed by the engineer car construction also standard units for use of bridge and building, track, signal, and water service departments, providing proper equipment to meet Santa Fe service demands and as comfortable living quarters as possible for Santa Fe men on the road. Often freight cars unsuitable for freight loading can be renovated and fitted up for work equipment service. Such reconversion, however, must meet established Santa Fe standards for work equipment.

New freight equipment acquired by the Santa Fe is purchased on contract from the nation's railway car builders in lots generally ranging from 500 to 2,000 cars. The Santa Fe's desires in regard to the construction of those cars are clearly specified, having been the subject of a great deal of study and preparation on the part of Santa Fe executives and departmental heads. Those matters clear through the engineer car construction who is responsible for the accuracy of specifications and drawings supplied car builders and the assurance that the latter follow Santa Fe requirements in detail.

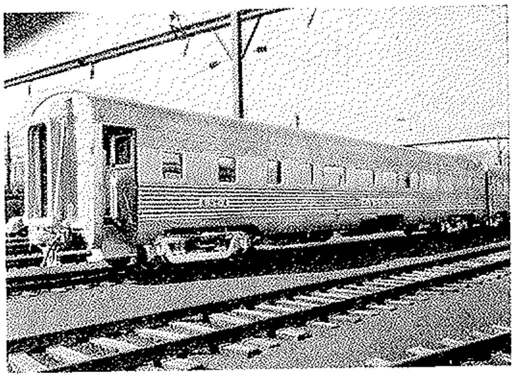
To accomplish the latter, a force of Santa Fe inspectors reporting to the engineer car construction, are stationed at each car builder's plant whenever Santa Fe cars are under construction. These inspectors check the work as it progresses. They have been educated in regard to Santa Fe desires in the matter of workmanship. They usually are loaned to the engineer car construction by other Santa Fe mechanical departments and in this way receive additional and valuable training in regard to freight car equipment.

The same inspection program is followed in relation to Santa Fe passenger cars and any special equipment which the Santa Fe has under construction in private car builders' plants. Another policy of the department is to educate carman apprentices and special apprentices of other mechanical department branches in drafting work on Santa Fe car equipment. The apprentices spend periods with regular draftsmen assisting in general layout drawings as well as detailed drawings, acquiring a basic knowledge of car construction.

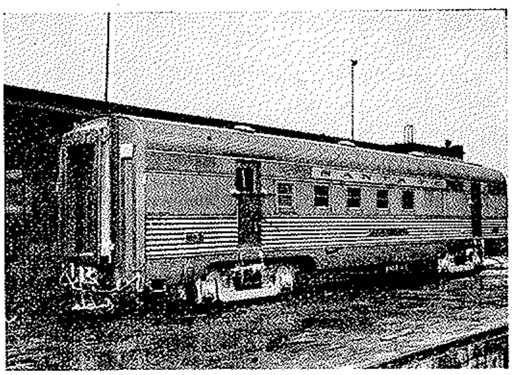
The car construction department handles Santa Fe system practices in regard to changes, modifications or improvements to existing Santa Fe cars rendering joint instructions to Santa Fe shops. Passenger equipment, from time to time, requires



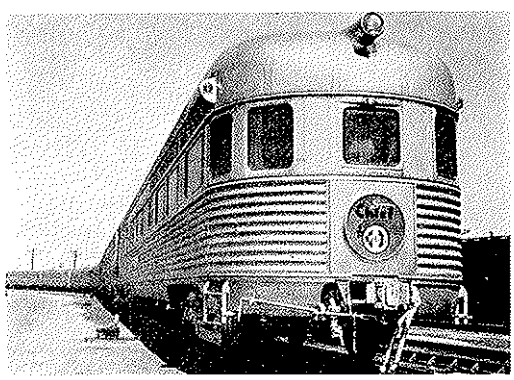
Stainless Steel Chair Car



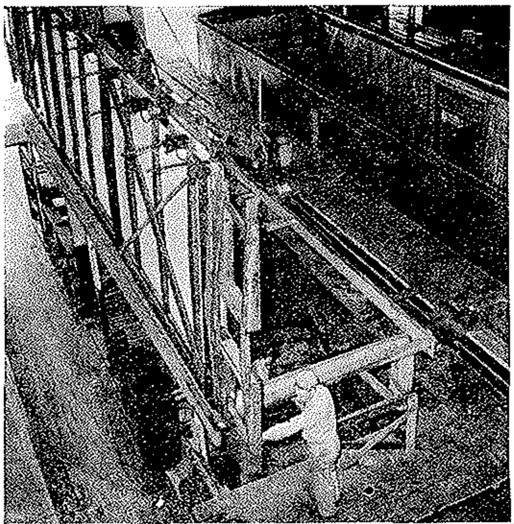
Club-lounge car

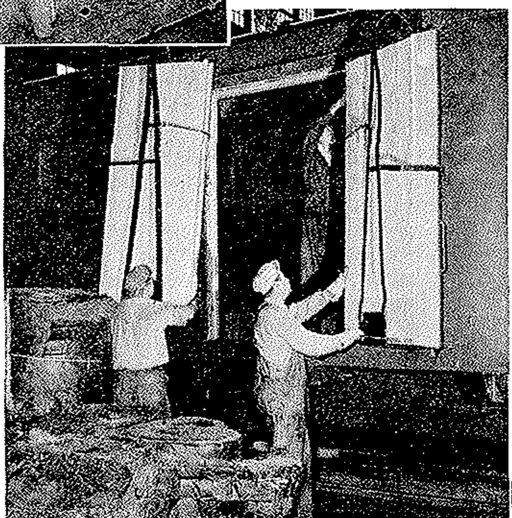


Streamlined Railway Mail Car



Rear view of observation oar



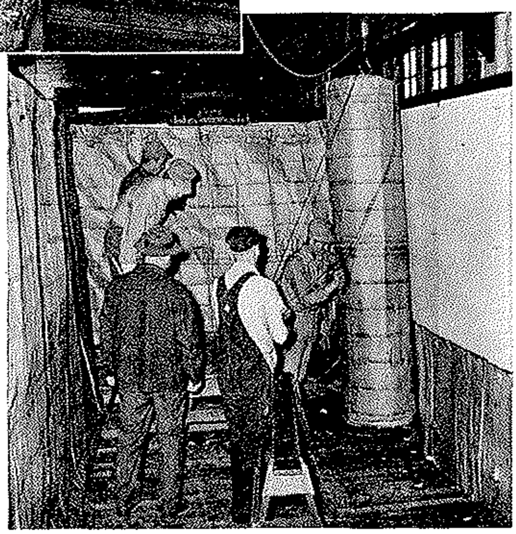


more modern type seats, interior trim and color schemes, carpeting, portable furniture, lighting fixtures and other features. Freight cars often require the installation of special loading facilities, particularly in the transportation of automobile and airplane parts. The latter consists of shapes and flats fabricated from metal and wood which securely protect the load. A number of Santa Fe automobile cars are equipped with Evans auto loaders, an adjustable device which permits the loading of three or four automobiles in one freight car. Other cars are equipped with Santa Fe devices or arrangements for handling automobile bodies, chassis, fenders, tanks and other parts, such devices being engineered by the car construction department.

All projects covering improvement or modification of passenger and freight cars require development of estimated cost of material, labor, and incidental charges. Folio records are maintained of the progress of all work projects on such equipment. Monthly reports are rendered the mechanical valuation engineer and others. There are numerous folios which furnish descriptive information of passenger and freight cars and these must be revised from time to time in order that all who use the folios on the Santa Fe system lines have up-to-date information on hand.

All projected changes and improvements to cars are covered by written specifications, bills of material and drawing lists, *supported by individual detail drawings of* parts and assembly involved. Layout drawings created include all details of superstructure, underframe and trucks. The drawings are listed and a bill of material made up to cover one complete car of the total number in a series being built or rebuilt.

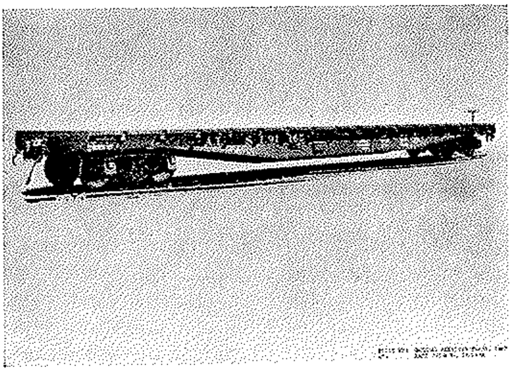
The files of the engineer car construction contain, by classes, some 250,000 master and detailed drawings of Santa Fe cars. Card record is maintained of all drawings, shop cards, bills of material, specifications, drawing lists and blueprints for use of draftsmen and others when needed to refer to drawings covering construction of Santa Fe cars. Card record also is kept of pattern or casting numbers issued for the different castings placed on passenger, freight and



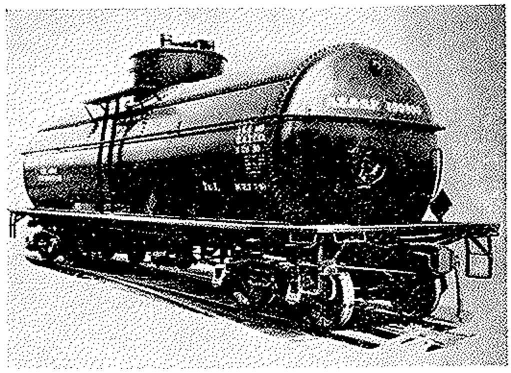
Typical scenes in the Wichita car shops. Top—Crane lifts new refrigerator car top for car at right. Center—Workmen install new doors on refrigerator car. Bottom-insulation being placed at end of S.F.R.D. car.

Caboose oar

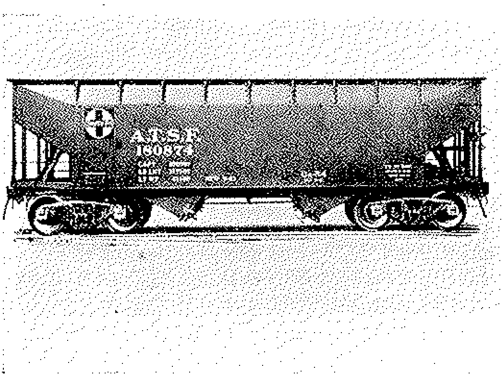
Refrigerator car



Sixty-foot flat car

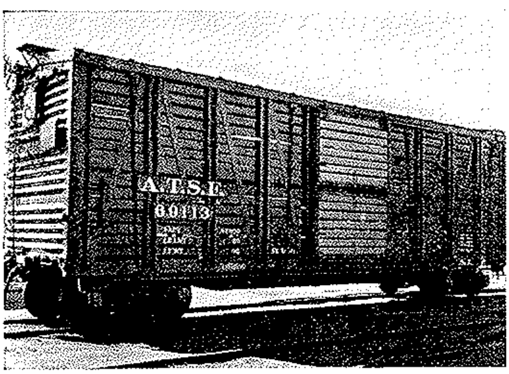


Tank car

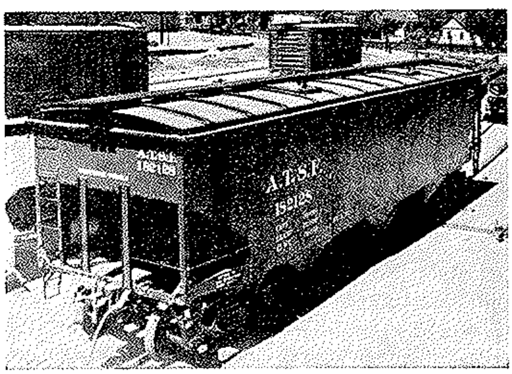


Gondola car

Box car



Double deck stock car



Covered hopper car

The files of the engineer of car construction contain, by classes, some 250,000 master and detailed drawings of Santa Fe cars. Here C. A. Carlson, draftsman, is shown in the file room.

work equipment cars. Many requests for blueprints covering individual parts or assemblies making up Santa Fe cars are received.

In the case of Santa Fe refrirerator department cars, rebuilding of superstructure often is required to meet present-day requirements for low temperatures. The matter of inside dimensions receives attention, length and width of car, together with other special features such as waterproof flooring which is laid over wood deck, circulating fans which provide an even temperature throughout the car and installation of convertible bulkheads. The latter provide a longer inside length when in converted position enabling a refrigerator car to be loaded with nonperishable goods when returning to the Southwest from eastern states.

Some Santa Fe boxcars have been provided with hinged end and side lining, permitting thorough cleaning of grit and dust behind the lining which prevents rotting from dampness. Other Santa Fe boxcars have roofs coated with an insulating material to take care of condensation from such cars when loaded with hot flour from the mills. Car floors roughened, dirty and greasy from previous loadings arc planed and sanded to permit safe loading of sacked commodities and others.

In the rebuilding programs, the classes of cars to he rebuilt and the numbers or series of cars in those classes is determined and set forth in the general memoranda of instructions issued by the engineer car construction to the superintendent of shops—to Topeka on box and other cars; to Wichita on refrigerator cars. The instructions, which may concern groups of cars ranging from 500 to more than 1,500 which it has been found advisable to rebuild or improve, set forth each step in the rebuilding program, accompanied by specifications, hill of material, drawings and other pertinent detai:. In addition to various mechanical department officers throughout the system, the general purchasing agent and other Santa Fe officers receive copies of the memoranda.

There remains the task of getting these cars to the shops from their present locations which may be on the Santa Fe's lines or those of other railways. The general superintendent of transportation and his car service department and the various mechanical superintendents are notified when material is on hand at the shops for the rebuilding program. Locating and directing of cars to the shops follows.

The detailed instructions concerning the rebuilding program inclnde all procedures. They begin with the stripping of the car and the disposal of ends, roofs and all parts so that such material may be stored and utilized for fullest reclaim value. The rebuilding task actually begins with the underframe and trucks. A sample instruction regarding the latter is quoted:

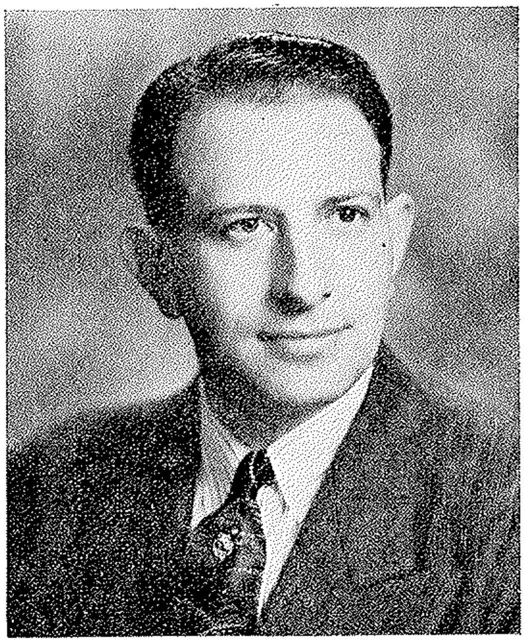
Underframe to he given thorough inspection and all necessary repairs made and underframe to he sandblasted. Underframe to be reinforced by application of intermediate "Z" bar floor supports attached with brackets to underframe members assembled as shown on drawings. The present trucks are to be maintained following specification of drawings carefully as to modification required for each class of car involved.

Instructions regarding draft gears, couplers, brakes, brake beams and other parts are detailed. Other major items inclnde details regarding the superstructure — sides, ends, roof, doors, flooring, running boards, side and end lining. On refrigerator cars, details on insulation, bulkheads, ventilators, plugs and other refrigeration or ventilation features are outlined. All those factors have been predetermined as essential and desirable for the service to which the cars will be put. The cost of rebuilding and other details incident thereto have been fully considered and approved.

It is a Santa Fe policy to maintain its car equipment in perfect condition and all procedures of the engineer car construction and staff are instituted for that purpose.

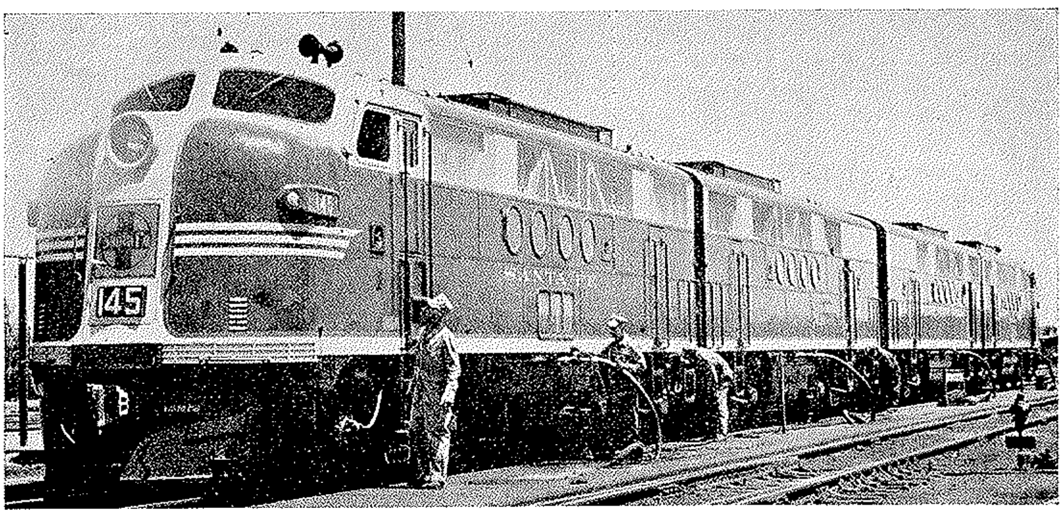
Supervisor of Diesel Engines

MAINTENANCE and operation of the Santa Fe's steadily broadening Diesel power—locomotives and facilities—are the responsibility of T. T. Blickle, superivsor of Diesel engines, Chicago, who prepares maintenance schedules, instructions regarding proper operation of Diesel equipment, and arranges for changes in design when necessary in the light of roadway and shop experience. The supervisor directs his assistants in special and periodic inspections of Santa Fe Diesel equipment and keeps abreast of all developments in this progressive field of railway motive power—all under the general direction of the assistant to vice-president in charge of operation and the general mechanical assistant.



T. T. Blickle, supervisor of Diesel engines, with headquarters in Chicago.

On his Chicago staff, the supervisor of Diesel engines has two assistant supervisors, one assists in the direction of Santa Fe Diesel operations on the Santa Fe's Eastern, Western and Gulf lines, assisted by Diesel maintainers located at Chicago, Shoptori, Chanute, Emporia, Arkansas City and Alhuquerque; the other heing assigned to follow up Diesel switch locomotives over the system. An assistant supervisor also is located at Los Angeles, directing the activities of Diesel maintainers at Los Angeles, San Diego, San Bernardino, Bakersfield, Richmond, Winslow and Alhuquerque; and fourteen assistant supervisors who work jointly with division master mechanics, riding Diesel locomotives, instructing Diesel engine crews, rendering inspection reports to mainte-



Crew servicing a Diesel freight locomotive at Winslow, Ariz. Photo shows the fuel man, inspector and brake shoe man, and at front of engine John Galvin, dispatching foreman.

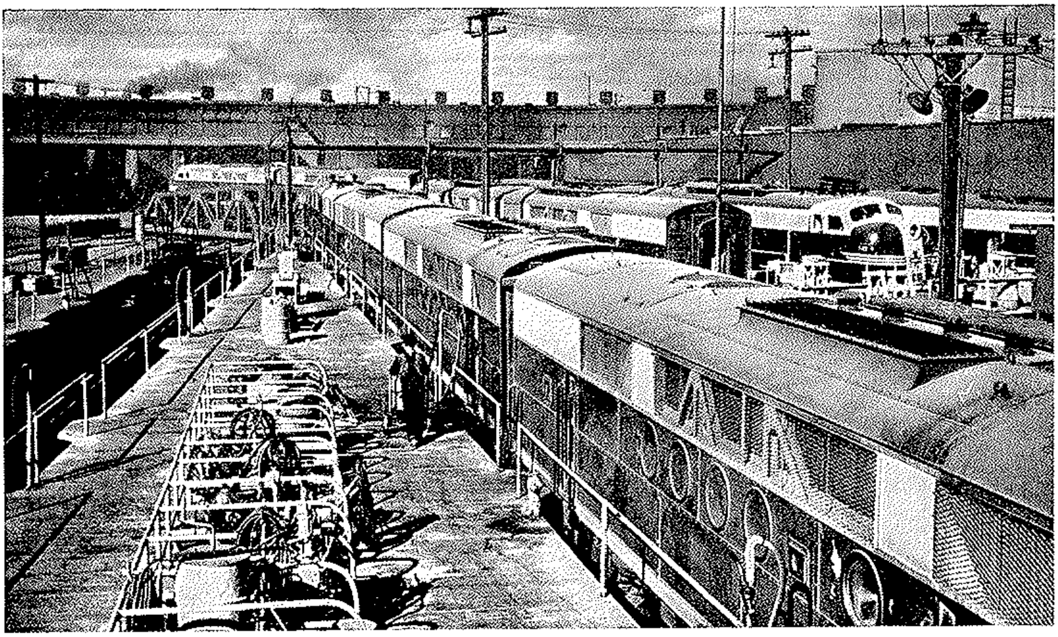
nance terminals and generally assisting and observing Diesel operational practices.

Locomotives and defective material records, acquisition of emergency material, personnel and related matters, are handled in Chicago by the assistant to supervisor of Diesel engines. Diesel maintainers ride the locomotives, checking the equipment, making repairs when needed, and providing the engine crew any necessary assistance. In some instances, the maintainers inspect locomotives while the latter are passing through terminals in order to determine if they are in proper condition. In all, there are thirty-two Diesel maintainers on the Santa Fe system lines.

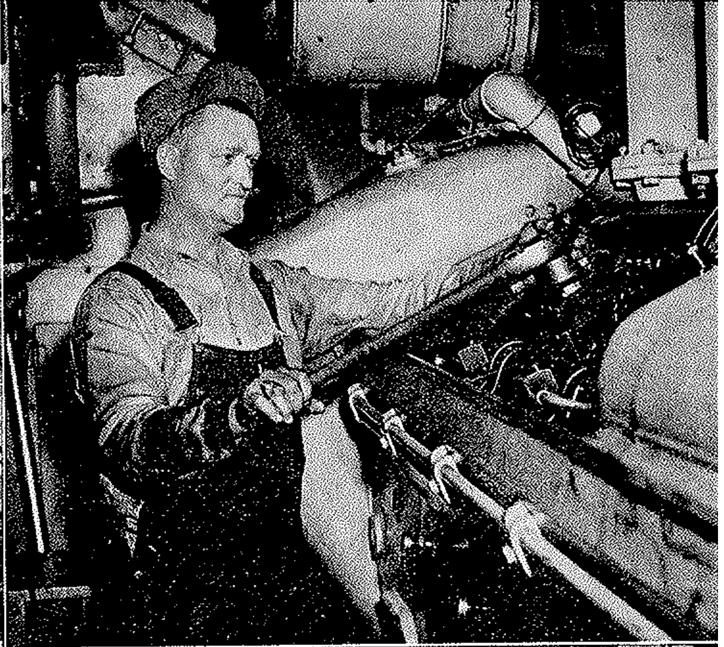
The Santa Fe's program of utilizing Diesel maintainers in shop maintenance (they formerly rode locomotives) was placed in effect during **1944.** Maintainers still complement the Super Chief and El Capitan on all runs. In order to assist the engine crews and shopmen in familiarizing themselves with Diesel-electric locomotives a school car was launched on the Santa Fe's Coast Lines in **1944.** Fourteen maintainers were promoted to assistant supervisor positions, and, with all road foremen of engines on the territory, were given a two weeks' training course at Electro-Motive Division's factory at LaGrange, Ill.

Since the first Diesel maintainer position was established on the Santa Fe in **1935,** two hundred men have received maintainer's training, fifty being promoted to various supervisory positions — master mechanic, shop foremen, Diesel foremen, electrical foremen, assistant supervisor and others. The ranking position, supervisor of Diesel engines, was created in **1935,** and a period of intense study in regard to all Diesel factors followed. It was necessary not only to acquaint Santa Fe mechanical department supervisors with this comparatively new railway motive power, but there remained for the Santa Fe to explore and initiate maintenance practice, and to install shop and roadway facilities. All supervision today is handled by Santa Fe trained men.

It was necessary to acquaint Santa Fe mechanical forces at various locations — Newton, Albuquerque, Winslow, Los Angeles and others — with details incident to Diesel-electric locomotive maintenance so that Diesels in transcontinental passenger service could be properly serviced en route and that there would be no delays in furnishing Diesel power for return trips.



Diesels by the dozen cluster around outdoor servicing platforms at Winslow. Turntable and roundhouse may be seen in background. Three of the six tracks for these outdoor platforms have deep, electrically-lighted pits, and each of the three tracks is 200 feet long, just enough space to accommodate all four units of a Diesel freight locomotive which is 194 feet, 4 inches long.



Various Deisel maintenance and repair procedures in Santa Fe shops:

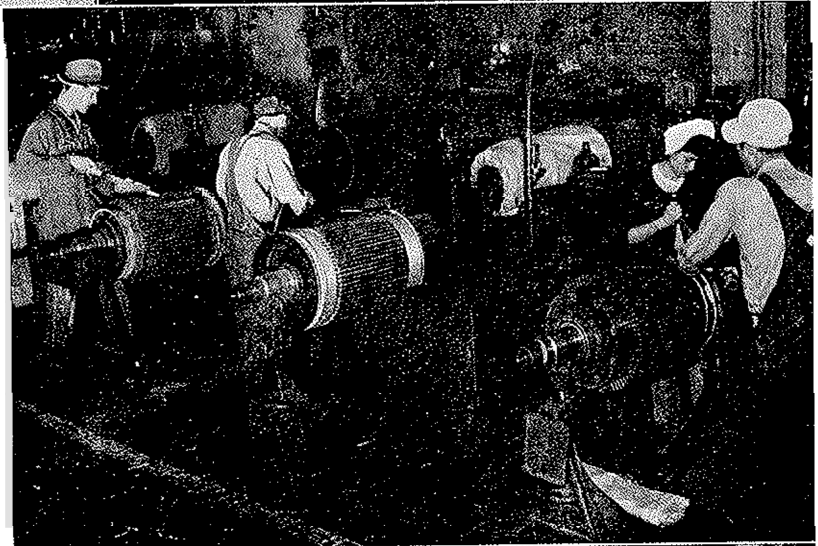
Upper left—Machinist Root and Machinist Apprentice Brown preparing gear train end to weld crack in dead air space in Diesel engine at Barstow.

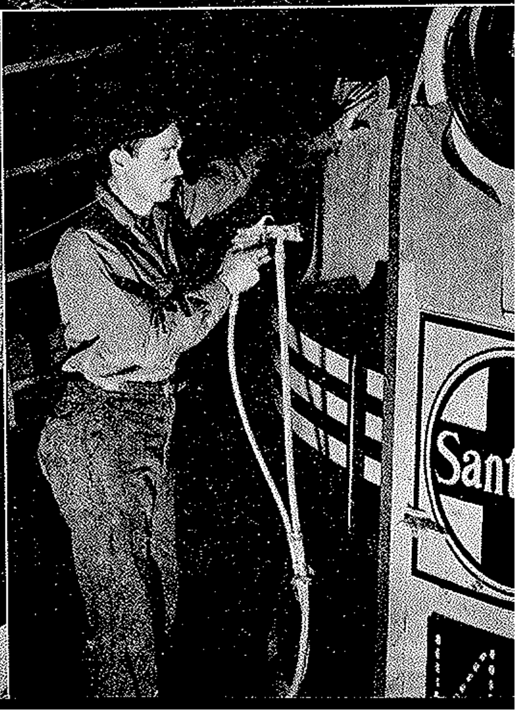
Upper right—Machinist Theime applying No. 8 assembly at Barstow Diesel repair shops.

Center—Armature repair work at the electric shop in the Diesel repair department, San Bernardino shops. Shows completed cross connecting for tension banding—wedging a new rewound armature and cleaning the core in preparation for a new rewinding.

Lower left—Rebuilding a Diesel engine in San Bernardino shops.

Lower right—R. S. Richardson, locomotive painter, shown spotting in red stripe on head end of freight Diesel at Barstow shops.





Many Santa Fe people interested themselves in this new field of motive power and the roster of those engaged in tasks incidental to Diesel operation and maintenance steadily increased as more and more Diesel power was acquired by the Santa Fe. When the territory west out of Winslow was Dieselized for freight service, it was necessary, within a period of two years, to acquaint approximately 2,500 Santa Fe shop and engine men with Diesel-electric freight locomotives.

The maintenance of Diesel-electric locomotives is based on preventive and progressive maintenance schedules which have been determined and established from the actual performance and operation of the locomotives since they were placed in service.

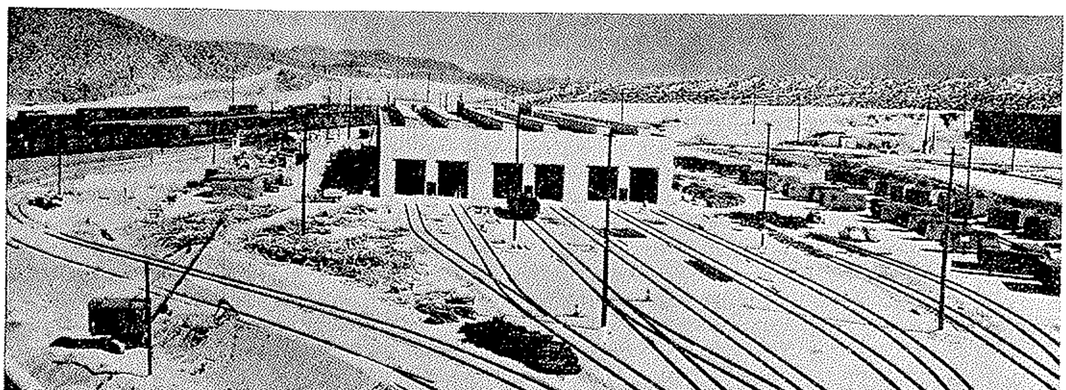
It must be appreciated that the use of Diesel power in railway service is still in the development stage. Further, that the Santa Fe had no precedents, chartering each course as it was confronted and, as is traditional with the Santa Fe mechanical department, adopting as standard only those practices which, after thorough test, have proven best for a particular purpose.

A complete record of all Diesel-electric locomotive parts such as pistons, cylinder heads and liners, crankshafts, traction motors and generators, is kept at the locomotive's assigned maintenance terminal; also complete records of maintenance and mileage of the various locomotive parts.

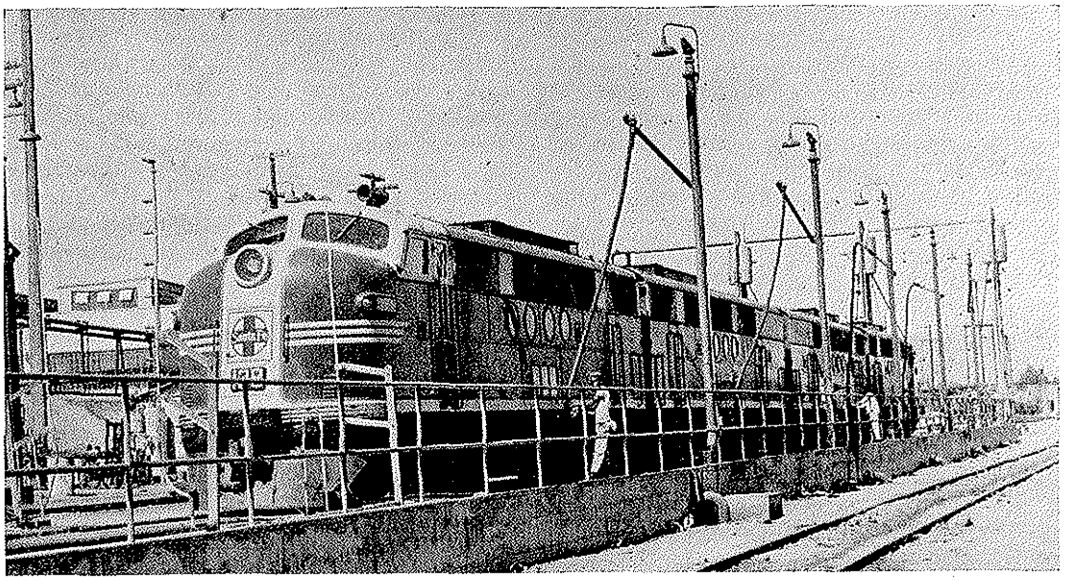
Present maintenance schedules for Diesel-electric locomotives do not include main generator or engine overhaul as no definite time has been established for those repairs. The various Diesel procedures are so new and developments so rapid, influenced by locality, traffic and many other factors, that some years must elapse before experiences and conditions can be catalogued and standard practices established. Present-day Diesel maintenance is based primarily on inspection. On the Santa Fe, this inspection routine is precise and thorough.

Santa Fe Diesel passenger locomotives are inspected at the time of and during the trip; monthly, quarterly, semi-annually and annually; and each 2,000, 10,000, 25,000, 50,000, 75,000, 100,000, 150,000, 200,000 and 500,000 miles. Various parts are given special treatment at those intervals. Other parts are treated in the light of their condition at time of inspection. Service life of wheels on Diesel passenger locomotives is approximately 250,000 miles, with machining each 84,000 miles on an average. Pistons and cylinder heads are removed on an average each 150,000 to 175,000 miles for inspection and servicing. Crankshaft bearings are inspected around each 100,000 miles. Cylinder liners are reconditioned when worn .020-inch after approximately 325,000 to 500,000 miles.

Santa Fe Diesel-electric freight locomotives operating under vastly different conditions are inspected at the time of and



Ribbons of steel, a network of tracks lead from Barstow yards to Santa Fe's new Diesel shop in background.



At the Barstow fueling station, this freight Diesel locomotive gets a new supply of fuel oil before heading back east to Winslow.

during the trip; also monthly, quarterly, semi-annually, annually, two-year, three-year, and each 2,000, 10,000, 25,000, 50,000, 75,000, 100,000 150,000, 200,000 and 500,000 miles. Various parts are given special treatment at those intervals. Other parts are treated in the light of their condition at time of inspection. The freight Diesels run on an average of 10,000 miles per month.

The maintenance of Diesel-electric switch locomotives is scheduled to he handled at the time of the daily, weekly, semi-monthly, monthly, quarterly, semi-annually, annually, two-year and four-year inspections. During that interval, all parts of the locomotive receive inspection and necessary repairs. Diesel switch locomotives are maintained and operated at thirty-three terminals embracing all grand divisions on the Santa Fe's system lines. Argentine, with an assignment of twenty-one, Chicago, with an assignment of fourteen, and Los Angeles, with an assignment of eleven, comprise the three largest groups of Santa Fe Diesel switchers in operation at terminals.

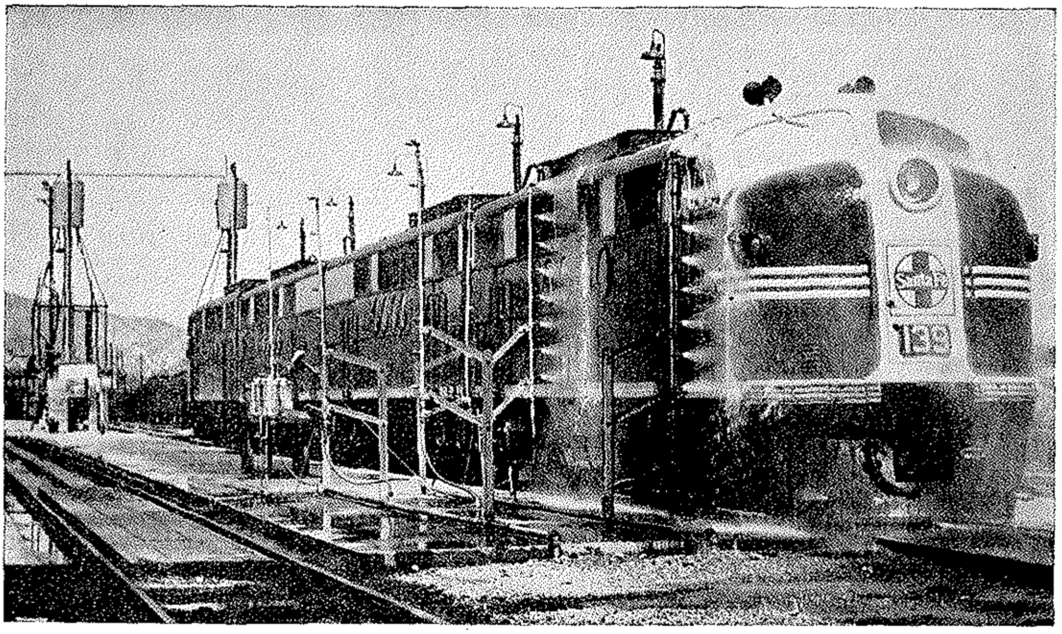
The Santa Fe established at Chicago, in 1939, the first Diesel locomotive shop owned and operated by an American railway. Here heavy repairs to the Santa Fe's fleet of Diesel passenger locomotives are made, as well as running repairs on all locomotives operating out of Chicago via Santa Fe. Diesel passenger locomotives also are maintained at Los Angeles, San Diego, Richmond, Bakersfield and Tulsa.

The Santa Fe will supplement its Diesel locomotive maintenance facilities with a new shop to be built at Kansas City, Mo., at an estimated cost of $1,000,000. If materials are available, it is expected that the plant can be completed by the end of this year.

Diesel freight locomotives are maintained at Winslow, Barstow, and San Bernardino, with heavy repairs at the latter point. Temporary facilities for maintaining Diesel freight locomotives were set up at Argentine, Kansas, in 1941. When Diesel freight locomotives were placed in operation on the Coast Lines in 1942, it was necessary to provide facilities for their maintenance at Winslow. Concrete ramps have been installed in a half-section of the existing roundhouse. Wheel work is handled by especially constructed transfer table which enables complete trucks to be changed out in two hours. Wheels are machined on an especially acquired lathe. Special fuel facilities, wash rack for trucks and sanding equipment are installed on inbound leads. Large fuel storage tanks and a distilling plant for making distilled water for Diesel engine cooling systems, 20,000 gallons per day capacity, are in use.

The San Bernardino Diesel maintenance facilities were installed in 1944 by reconverting a portion of the existing tank shop. Two special tracks for rebuilding Diesel engines on dollys after they have been dismantled are provided. There are large cleaning tanks for submerging the engine crank cases, a reconditioning room equipped with special lighting for rebuilding engine parts and assembling the engines. Diesel engines are rebuilt under conditions comparable to an engine factory. All annual inspections, as well as all heavy repairs on Diesel freight locomotives receiving heavy repairs, are subjected to a four-hour full-load test before being dispatched for service. The first locomotive dismantled and rebuilt at San Bernardino operated successfully in all respects. An electric repair shop for overhauling traction motors and generators of all types of Diesel locomotives is located at San Bernardino. Formerly all traction motors and generators were returned to the manufacturer for repairs. This shop is equipped with thermostatically controlled baking ovens and soldering pits, dynamic balancing machine, banding and undercutting machines, vacuum impregnating machine, motor generator set for operating motors, as well as many miscellaneous tools and an overhead crane.

Santa Fe's Diesel shop at Barstow is the largest and most modern Diesel repair shop on the Santa Fe. Of new design, the shop has concrete pits and ramps with pipe connections installed at proper locations for furnishing lubricating oil and distilled water to each engine as well as pipe connections for draining lubricating oil from each engine. The shop has no turntable (Diesel freight locomotives now operate double-end). Original plans called for six stalls each accommodating a four-unit 5,400-h.p. locomotive. The capacity will be expanded, as additional maintenance is centered at Barstow. Sanding and washing facilities, machine, carpenter, pipe, parts reconditioning, a parts and filter cleaning, and a paint shop are included at Barstow.



View of freight Diesel being washed at the Barstow shops. The washing device was invented *by* members of the Santa Fe shop forces.

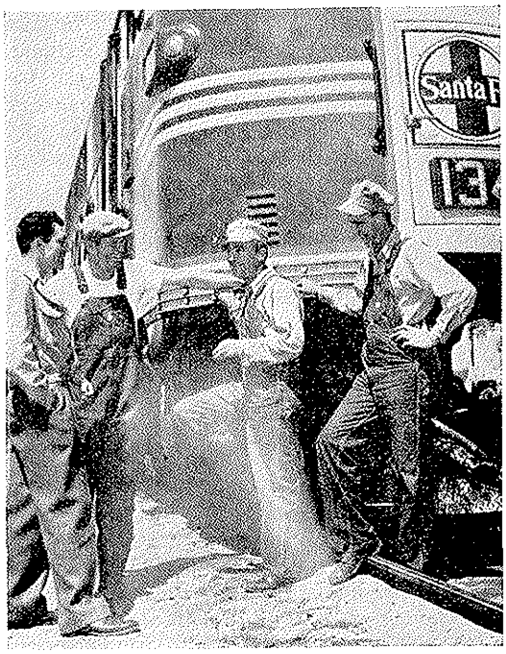
It is possible to maintain Diesel-electric locomotives with very limited facilities when only a few locomotives are involved. With large groups, however, special facilities must be provided in order that work may be properly done and locomotive detention time reduced all possible. Facilities at terminals where a few Diesel locomotives are maintained—Los Angeles, Richmond, Tulsa, San Diego and other Santa Fe system points—usually consist of one or more stalls at the roundhouse with ramps applied on each side to allow work to be handled on same level as engine room.

Liberal use of alloys has been made in the design and construction of each Santa Fe Diesel unit thus securing maximum strength with minimum weight. Crankshafts are of high carbon steel forgings. Some of the hearing surfaces have been hardened by a special process. Connecting rods are alloy steel forgings. Pistons are drop-forged aluminum or cast malleable iron. Piston pins are of high carbon steel. Cylinder liners and cylinder heads are of east iron. Valves are special heat resistant steel. Engine frames and cylinder blocks are of high tensile carbon-molybdenum steel. Electric welding has been used to fabricate most parts of Santa Fe Diesel locomotives. Cover sheets are of stainless steel. In the operation of Diesel freight equipment, Winslow-Barstow, a 15 x 62 gear ratio was determined most adaptable and useful after exhaustive tests.

Representatives of many railways in the United States have observed the Santa Fe's Diesel operations. Some foreign countries have been represented. The Santa Fe has worked closely with Diesel-electric locomotive builders and that cordial relationship has contributed much toward the success of Santa Fe Diesel operations. The Santa Fe, in conjunction with Diesel locomotive builders, has tests under way at all times.

During the short period of its intensified development, the Diesel-electric locomotive has become highly regarded in passenger, freight and switching operations. The Diesel principle, as adapted to Santa Fe motive power, clearly follows the principles embodied in the discovery by Rudolph Diesel, the German engineer, born in Paris in 1858. Rudolph Diesel's experiments proved that the high compression of air drawn into a cylinder generated a degree of heat sufficient to explode the oil and powdered coal which he caused to be injected into the cylinder. That is the basic Diesel principle — the exploding or firing of combustion fuel, ignited by heat generated by compressing pure air in the Diesel engine cylinder. In a Diesel engine, only air is taken into the cylinder on intake stroke, and fuel is introduced later and separately. The fuel is ignited because the air has been made as hot as red hot iron by the compression.

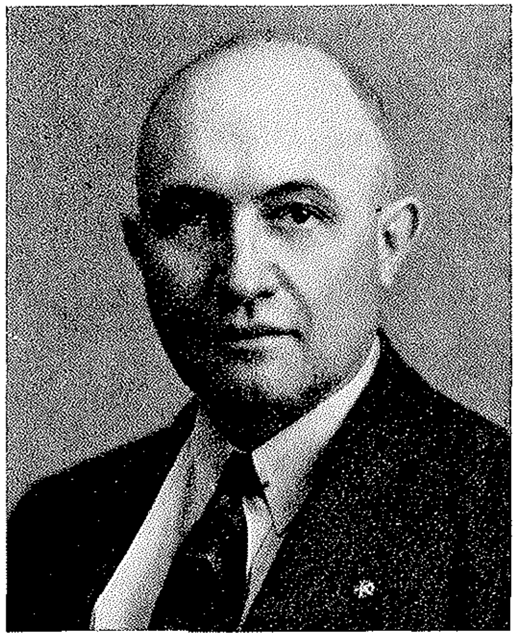
When the pure air which has been drawn into Diesel engine's cylinders has been compressed to approximately 660 pounds per square inch pressure, the temperature of the air is raised to approximately 1000° F., and a device known as the injector forces a small amount of fuel through a spray nozzle located in the cylinder. The nozzle has six small openings each about .010-inch in diameter. This results in fuel being atomized, throwing a fine oil fog into the cylinder. The high temperature of air in the cylinder ignites the fuel and the burning fuel expands, forcing the piston downward on power stroke. In the four stroke cycle engine, injection and explosion take place on the second upward stroke of the piston; in the two stroke cycle, on every upward stroke of the piston.



Tom Willis, assistant Diesel supervisor; S. A. Reed, brakeman; F. H. Flowers, engineer, and R. T. Fields, fireman, standing beside freight Diesel at Barstow. Supervisor Willis is instructing the engine crew in correct Diesel operation.

The Test Department

THE Santa Fe's test department, with Walter Bohnstengel, engineer of tests, Topeka, is a division of the mechanical department functioning as a test, inspection and control department for materials in use on the Santa Fe system lines. Scientific introspection begins with the right of way—the ground itself, ballast, ties, rails and bridges. It includes Santa Fe motive power, cars, power plants and other equipment, machines and supplies in service. The test department, in conjunction with other Santa Fe departments, analyzes operational and engineering procedures to the end that maximum efficiency may be obtained in relation to materials and equipment utilized. Service to Santa Fe patrons, comfort, safety, and economy of operation, are guiding factors in the work of the test department.



Walter Bohnstengel, engineer tests, with headquarters in Topeka. Kan.

The engineer of tests has a staff of assistants who are graduates of technical colleges and universities, with long periods of Santa Fe training, qualifying the department to handle the many matters which are referred to it. Standard specifications are developed as an aid to Santa Fe departments and to manufacturers supplying Santa Fe needs. That often is followed by inspection at the factory, tests in the department's physical and chemical laboratories, and study and observance of the materials and devices in actual service. Specifications developed are an especial aid to the purchasing department.

Much of the test department's work is in conjunction with various divisions and committees within the Association of American Railroads, the American Society of Mechanical Engineers, the American Society for Testing Materials. American Railway Engineering Association, [illegible] can Chemical Society, and [illegible] bodies, test department members serving on committees within those organizations.

An assistant engineer of tests—the department has four, also chemists, metallurgists, and various assistants—handles Diesel and steam locomotive performance tests, tonnage ratings, power assignments, hauling capacities, track or rail stresses, dynamometer car tests and related studies. Another assistant engineer of tests is engaged on locomotive and power plant tests, as consultant in physical laboratory procedures, and tests of miscellaneous appliances. The Santa Fe, and all railways, purchase appliances and devices developed by manufacturers which rarely can be adopted to 'actual service without some modifications or revisions to meet the railway's particular requirements. That is because the manufacturer does not, in all instances, have direct contact with the usage of his product. The Santa Fe test department is interested solely in bringing such devices and appliances to a stage of development essential to Santa Fe needs.

Another assistant engineer, with the aid of chemists and analysts, directs the analysis and control of boiler water treatment, analysis of paints, varnishes, thinners and substitutes, weed killing chemical applications (on right of ways) and other materials. The water treatment program on a transcontinental railway may be likened to the water works of a metropolitan city; elimination of incrusting boiler solids, however, necessitated a more involved treatment than is required with ordinary drinking water.

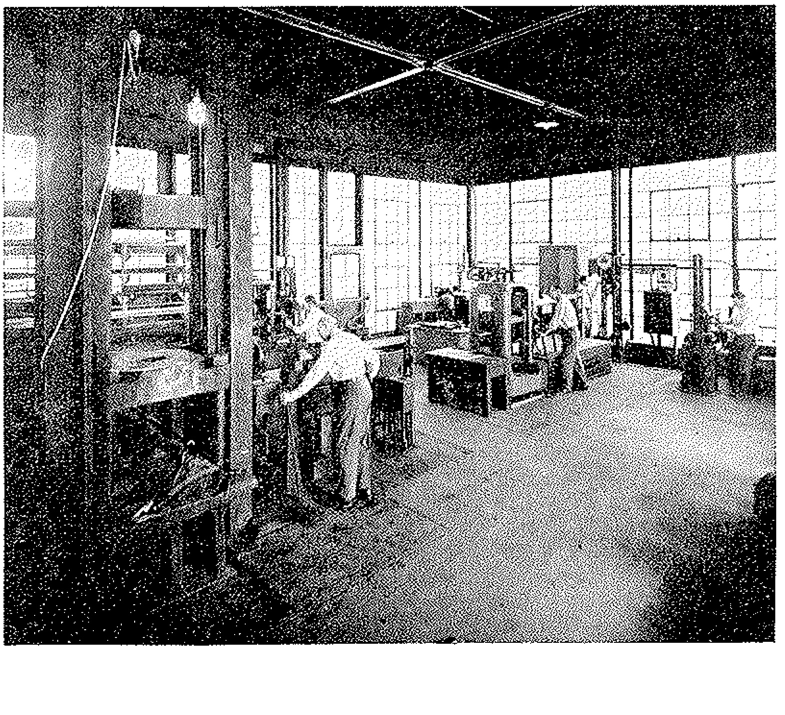
Laboratory work includes acceptance analyses of steels, metals and alloys, lubricants and fuels, and investigation analyses of failed and unsatisfactory materials. Metallurgists and others investigate the failed metal parts, also handle tests of building and track materials—cement, brick, sand, concrete, ties, timber, ballast and other items; also prescribe heat treatments for new materials, shop forgings, and other parts, to obtain needed physical properties including control of the fabrication of some 1,500 car and locomotive springs monthly at Topeka shops.

In the physical laboratory, general physical tests, sample preparations, meter and instrument calibration, failed material classification, check of failed rail and the breaking of defective rails removed are handled. All ladders, levels, track gauges, castings, locomotive seats, tarpaulins and other items fabricated at Topeka shops are inspected.

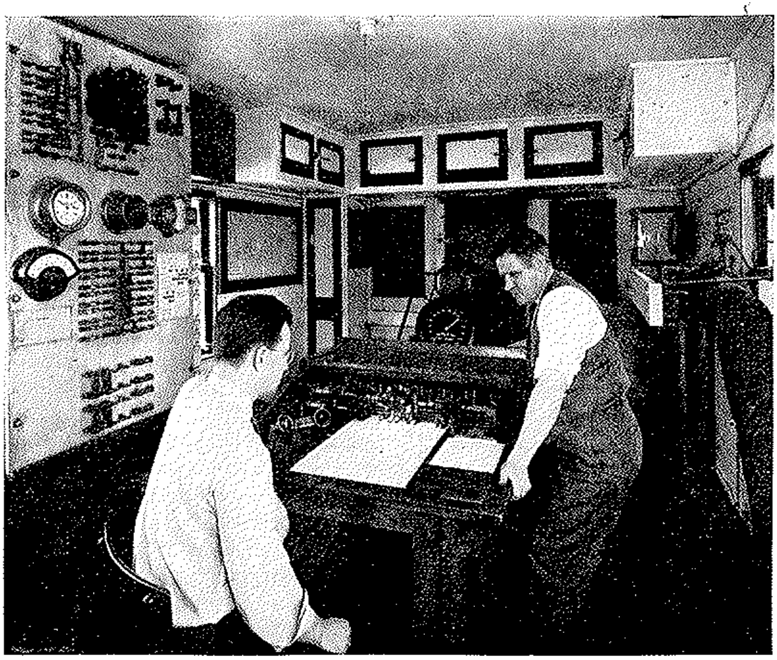
Procedures of the test department are thorough in application. Tests of iron and steel, which include physical and chemical, micro and macro examinations, tensile strength, impact resistance and hardness, are aided by modern testing machines and equipment. Insulating materials, tie plates and rail joints, boiler steel, boiler tubes and boiler performances, cylinders, rods, crank pins, wheels, axles, tires, draft gears, air brakes, superheaters, feed water heaters, boosters, air-conditioning units, and many other items including the riding of equipment to determine its riding qualities are included in the test department's program.

The testing of devices presented by inventors or manufacturers usually involves the simulating as closely as possible in the laboratory of service conditions on the road; or, when necessary, testing on the road. The latter can involve elaborate preparation and equipment (as in the case of Diesel power, new types of cars, braking equipment, and iron), and can only be undertaken when the device or equipment is deemed worthy.

The test department's laboratory equipment includes a dozen static testing machines, ranging in capacity from a fraction of a pound to 600,000 pounds, used in breaking iron, steel, rubber, cloth, paper, timber, concrete and other materials. There is an impact testing machine for small representative specimens, and an American Railway Engineering Association standard drop testing machine for breaking up full size rails and axles, and complete shop equipment for preparing and handling test specimens. The structure of materials is examined and photographed by photo-micrographs equipment. Apparatus for analyses of steel, fuels and lubricants, motion picture projectors and



Section of physical test laboratory at Topeka. Machine in left foreground is 600,000-pound capacity tension or compression screw type testing machine; others, left to right, are 100,000-pound and 300,000-pound capacity machines, textile tester, and 10,000-pound capacity tension or compression machine.



Interior of dynamometer car showing Chronograph which records drawbar pull, speed, brake application, car travel, location and time while car is in the train directly behind locomotive in actual road service. Throttle position, boiler pressure and other data are telephoned from observer in cab to operator and entered on record. Control positions on Diesel locomotives are automatically recorded.

complete photographic equipment (still and motion) machines, for abrasive test of rock and brick, a moist room in which are cured cement briquettes and concrete samples awaiting test, furnaces with pyrometers for testing fire brick at temperatures as high as 3,000 degrees F., and a refrigerated room and machine for testing lubricating oils under temperatures as low as fifty degrees below zero, are among the equipment utilized.

Locomotive valve oil, car oil and other oils and lubricants are subject to service and laboratory tests. There are special lubricants for special purposes and others to meet peculiar conditions. It is a test department responsibility to determine that usage and to provide chemical analysis of oils. Passenger cars operated transcontinentally during winter months often are subjected to temperature changes ranging from 90° F., to below zero. Freightcars, which are often interchanged with Canadian lines, experience even greater temperature ranges. Extreme low temperatures cause some car oils to change character. Stickiness permits waste-grab and hot boxes result.

The test department cold room permits tests of the properties of oils at low temperatures to prevent improper usage. Cold room machinery consists of a pair of wheels mounted on an axle with standard journals, journal boxes and brasses, so designed that loads can be placed on the bearings and the wheels rotated as in service. Temperature is dropped to as low as fifty degrees below zero. A study of various oils with the aid of this equipment, discloses those which become sticky and permit waste-grab. Oils can he produced with sufficiently high viscosity for summer service yet able to withstand low winter temperatures.

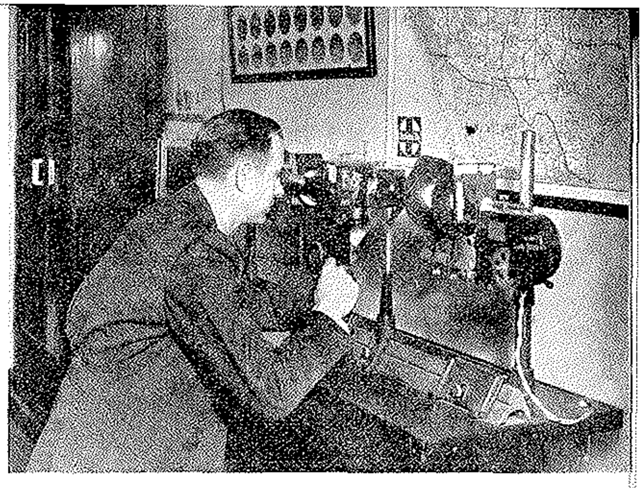
A dynamometer car is used in making locomotive power performance and tonnage tests. A power plant test car is moved from one power plant to another. Two rail flaw detector cars, operated under the general direction of the Santa Fe's chief engineer system, test from ten to forty miles of track per day. One car uses current through the rail and suitable radio tubes and amplifiers indicating defects in the rails; the other is of the magnetic type. When defects are indicated, detailed hand tests are made with a millivolt meter. If defect is harmful, rail is marked for removal. When such failures reach a designated numher, all rails in that heat are removed from main line service. If defects are transverse fissures, the rails are eventually sent to Topeka where the test department breaks the rails either by lifting and dropping or by placing under a drop testing machine. That insures a defective rail definitely out of service and also is a check on the accuracy of the online test.

The dynamometer car is designed to

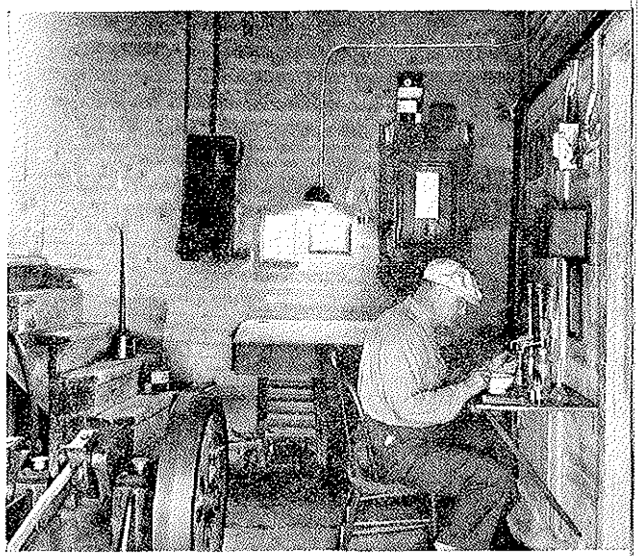
handle the pull of the largest locomotive and to record a buff of more than a million pounds at the draw bar. Equipment of the car includes the dynamometer, chronograph and other recording apparatus, switchboard, gauge board and living quarters for the crew. On a continuous chart, the chronograph simultaneously records by means of electrically or mechanically operated pens, the drawbar pull or huff, integrator record from which the power output is determined, speed, amount of fuel fired, air pressure in train line and in brake cylinder, time in six-seconds and one-minute intervals; also record of mile posts, stations and other land marks (reported by observer in cupola), the locations where indicator cards showing steam distribution in cylinders and valves are taken by observer riding locomotive, and the boiler pressure and throttle and reverse lever settings telephoned by an observer in the locomotive cab.

Dynamometer car studies determine whether the maximum efficiency of the locomotive is obtained, the amount of fuel and water consumed, the type of locomotive required for service on a particular territory, and the tonnage and number of cars in train that can be handled most economically over different districts in relation to class of locomotive, grade, fuel, water and time between terminals. The car also is used in the study of resistance, the advisability of grade reductions, in testing various types of brake equipment, in determining the service value of locomotive and car devices, and many other features pertaining to equipment and train operation. Considerable work has been done by the test department in the matter of starting and stopping trains, and the economies effected by eliminating stops and slowdowns.

The power plant test car is operated in conjunction with equipment at the plants. The car's equipment includes sensitive instruments which indicate and record the amount of steam which flows from the boilers, temperatures and pressures, draft in fireboxes, and the smoke and heat which goes out the stack. Steam, water and compressed air as distributed to various facilities and the electrical output of the generators are measured. A gas calorimeter and gas density balance are provided for analysis of natural gas at power plants where it is used for fuel. The gas analysis may he satisfactorily made on the test car; coal and fuel oil samples are forwarded

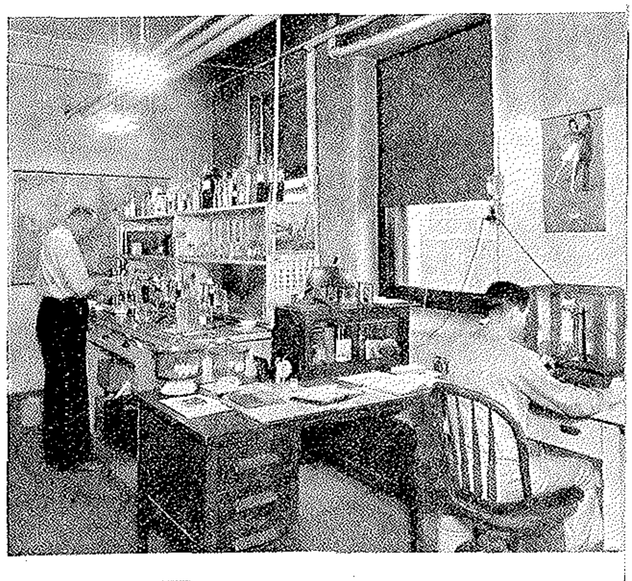


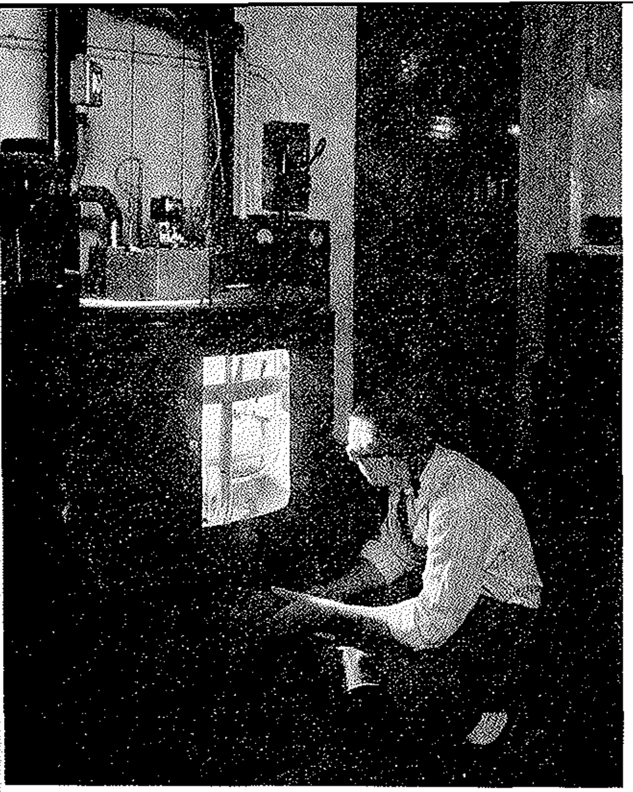
Metallurgist examining specimen of steel in photo-microscope.



Traveling chemist checking water treatment at treating plant on line.

Section of water analysis laboratory.





Weatherometer for accelerated weathering tests in which samples of paint or other materials are exposed to ultra-violet light and water spray, one day exposure being equivalent to as much as 25 days of outdoor weathering.

to Topeka for laboratory analysis. Plant costs are accurately determined, irregularities are corrected, and desirable practices disseminated among Santa Fe power plants.

Water is treated at various points throughout the Santa Fe's system lines to render it suitable for use as locomotive boiler feed water, drinking and other purposes. Analysis and control of treatment is centered at the test department laboratory in Topeka. Supervision of boiler feed water on the road is handled by nine assistant chemists who cover the Santa Fe's twenty-three local operating divisions. These men visit some 265 water treating plants throughout the territory, making field checks and prescribing treatment as water supplies experience change. Chemists at Topeka analyze samples of the water sent to Topeka. The Santa Fe has some 600 water pumping stations.

Water is one of the most essential natural resources. It is a good solvent for many materials — solids, liquids and gases — and seldom is found in a pure state. At some large terminals, up to 2,000,000 gallons per day are required. Water, as found, usually contains quantities of salts — limestone dissolves and produces bicarbonate of lime; dolomite limestone gives bicarbonate of both lime and magnesium; gypsum gives sulphate of lime; salt gives sodium chloride, etc. Those salts and other impurities are carried into locomotive boilers and deposited as sludge or scale as the water evaporates; they also decompose the metal and cause foaming. None of those substances volatilize except at much higher temperatures than are attained in locomotive boilers. A small amount of scale on the heating surfaces of a locomotive boiler quickly impairs its efficiency, clean surfaces having better heat conductivity.

Before such water is furnished the locomotive it is possible to remove some of the salts by the addition of predetermined amounts of lime and soda ash then allowing time for the suspended matter to settle out. Some waters may be more economically treated with other chemicals which help to suspend the sludge in the boiler so that it can be removed by blowing out some of the water. The kind of treatment is determined after the water has been analyzed and its impurity content known. Overtreatments must be avoided as they are equally harmful. The Santa Fe, in 1904, pioneered the use of chemicals in the treatment of locomotive boiler water.

The analysis and check of paint used by the Santa Fe on buildings and equipment is an important phase of test department activity. The composition of materials purchased must meet specifications. Weathering tests are made to determine which composition gives the best protection and service. Use is made of outside weather racks which provide exposure to sunshine, rain, heat and cold, and an ingenious "weatherometer" which produces accelerated weathering conditions. Chemical control of weed growth in track ballast requires chemical analysis of materials used. A special car and series of tank cars, operating on the Santa Fe's main lines, Chicago to Los Angeles and San Francisco to Galveston, perform this weed-control task, covering thirty to fifty miles per day. Car and locomotive washing compounds also are investigated. Substantial economics have been developed in regard to cleaning and antifoam compounds.

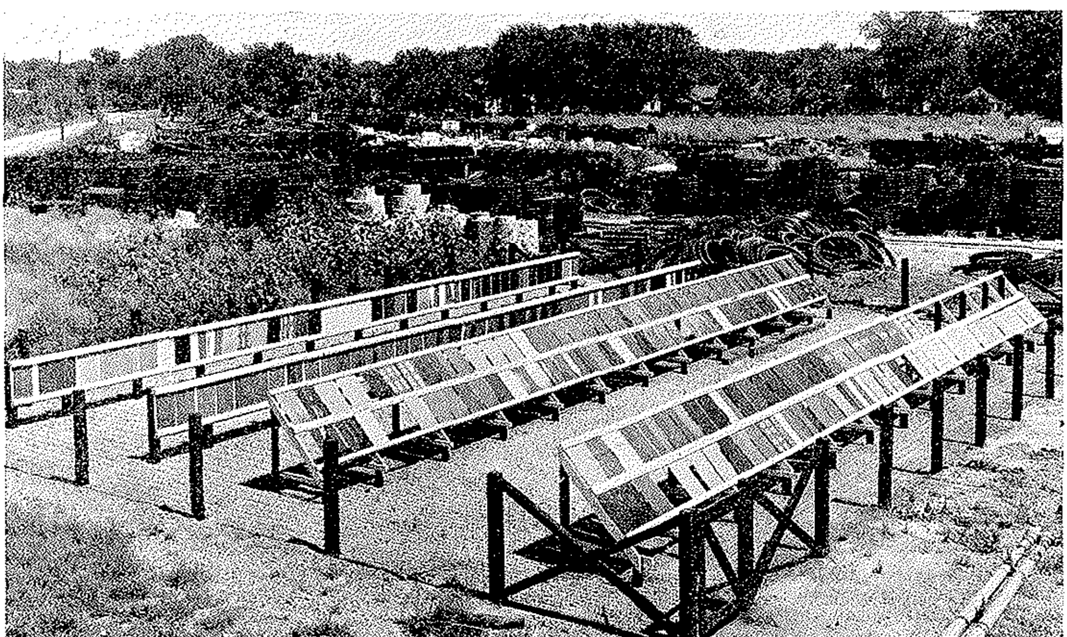
The test department reconditions, at Topeka, Diesel locomotive lubricating oil and roller bearing oil for the Santa Fe system. Crank case oil is heated, washed, filtered, and cleaned. Laboratory control is exercised to guarantee Santa Fe standards in the reconditioned product. Seventy-five hundred gallons of lubricating oil are reconditioned each week.

In addition to photographing locomotives, cars and equipment, track, ties, broken, impaired or failed parts, various tests and trial runs, the test department photographs scenes of accidents and other mishaps as a part of the technical analysis provided by the test department in the matter of claims filed against the company. Such photographi,: work is invaluable in the appraisal of damage and extent of the liability which may or may not be assumed by the Santa Fe. Analysis also is made of transported materials for which claims are filed. That includes analysis of the materials and of conditions surrounding the alleged damage.

The test department keeps in touch with the U. S. Bureau of Standards, Washington, D. C., and with the work being done by manufacturers and by other railways. Many months of road tests, in conjunction with manufacturers, preceded the introduction of Diesel-electric power in the various Santa Fe services. By co-operation with Association of American Railroads, study of Santa Fe locomotives in track stress test at Harvard, Ill., was made possible. Data on ride performance of various car trucks was obtained by working with manufacturers in collaboration with the American Steel Foundries Company, the latter's two especially equipped test cars being operated in high speed Santa Fe passenger trains between Chicago and Shopton.

Members of the test department are active on various committees within the Association of American Railroads, and the Santa Fe participates first-hand in the findings of those committees. Noteworthy are the committees for specifications for materials, and coupler and draft gear, draft gear tests being undertaken at the Association Laboratory, Purdue University. Through its test department, the Santa Fe is able to keep abreast of and anticipate developments in railway technology.

In these days of inncvations, a railway's test department is invaluable. It not only provides a scientific short cut, but it has the worthy vocation of aiding the railway to progress along well-defined lines. New materials put on the market and unusual circumstances in relation to almost any happening on the Santa Fe may come its way. The result is increased efficiency in railway operation with ultimate lowered costs for the railway. Care is exer-



Outdoor Weather exposure racks for check of samples tested in weatherometer; driving tire stock in background.

Weed killer chemical being applied on ballast to eliminate weed growth

cised to avoid undue expense on the part of manufacturers of materials and devices for Santa Fe use by eliminating from specifications items which are of no particular benefit.

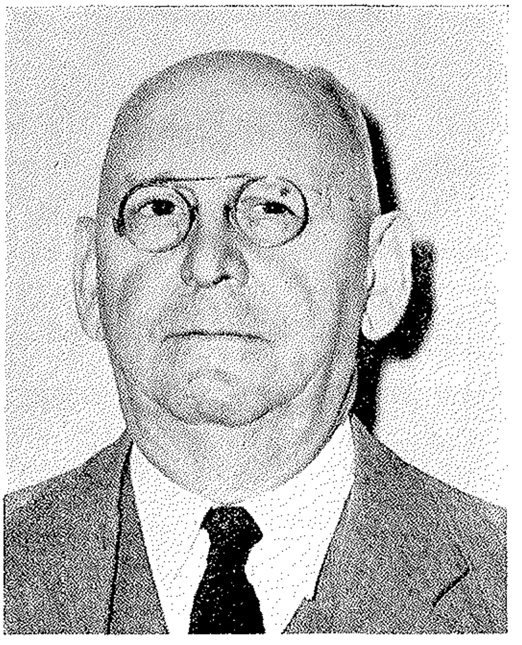
Considerable detail work is involved in the preparation of the test department's various reports and findings. That involves problems of determination and collection as well as presentation in an accurate understandable form. The department's chief clerk and staff are intrusted with these exacting duties, also the details incident to arranging for tests and accelerating their execution. Assistants also check speed rolls removed from locomotive speed recorders, reporting speed violations to the operating department for corrective handling. Control of train speeds is an important factor in train operation.

Most of the investigations of the test department relate to the work of the Santa Fe's mechanical, engineering, purchasing, operating, industrial, safety and claim departments. All Santa Fe departments, however, are aided directly or indirectly as all may have occasion to call upon the test department for assistance in the course of daily operations.

The Shop Extensions Department

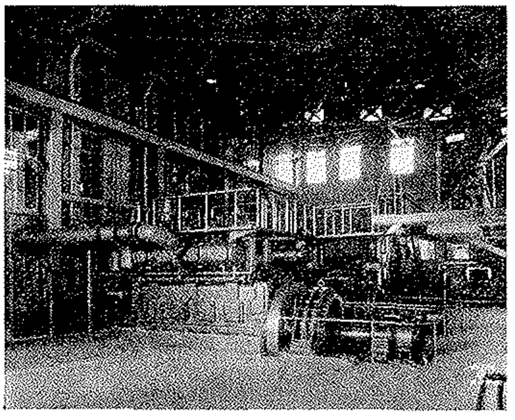
THE Santa Fe's engineer of shop extensions, Barton P. Phelps, Topeka, directs the functions of the shop extensions department, founded in 1901, and those responsibilities formerly embraced by the electrical engineer. The latter department was founded in 1903 and was consolidated with the shop extensions department in 1932.

In order that a railway may function with the precision demanded by the service ideals which it has established, special facilities — shops, roundhouses, maintenance plants, machines and tools — are necessary to insure that locomotives, cars and other equipment are maintained in a state of exact and constant repair. The installations for servicing and maintaining motive power and equipment, must, in so far as possible, harmonize with anticipated future needs. That involves considerable investigation and forethought on the part of Santa Fe executives. On the Santa Fe's 13,147 operated miles, it is a continuous problem the details of which are a special function of the shop extensions department.



Barton P. Phelps, engineer of shop extensions, with headquarters in Topeka, Kan.

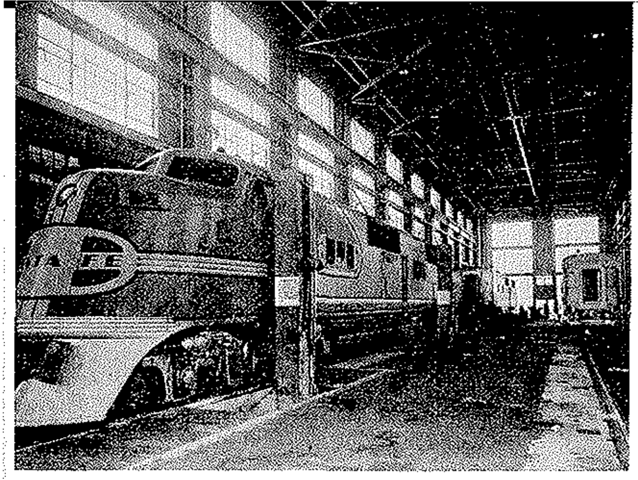
The work of the department falls under two classifications, mechanical and electrical. The mechanical section, staffed by an assistant engineer of shop extensions, with foremen and crews operating throughout the system lines, is engaged principally in the development and improvement of shops and repair facilities. The electrical section, staffed by an assistant engineer of shop extensions, with foremen and crews and inspectors, has cognizance over all electric light and power installations on the Santa Fe system, except telegraph, signal and storage battery installations, passenger car axle lighting and air-conditioning. General supervision of the maintenance of gas-electric cars in Santa Fe service is the responsibility of the department's supervisor of gas-electric cars.



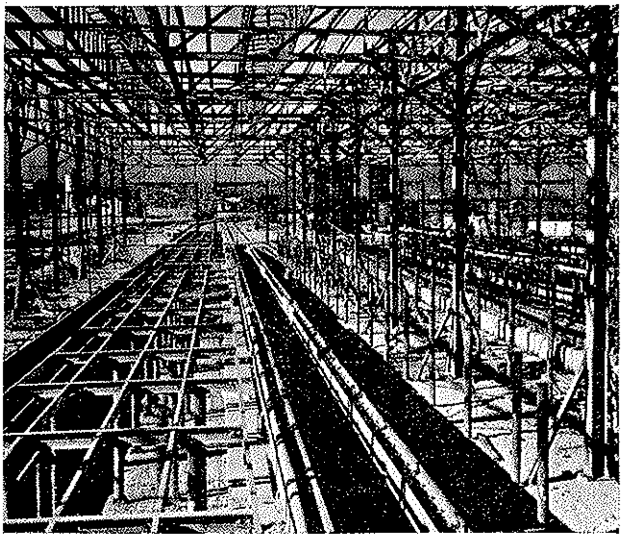
Interior of Santa Fe power plant at Grand Canyon, Ariz.

The work of the mechanical section begins with the formulation of studies of proposed new mechanical facilities such as roundhouses, locomotive and car repair shops and Diesel maintenance houses. That involves the development of preliminary plans to determine the general size and design of the buildings and their location on shop grounds, the track arrangement, and the machine-tool layout to handle the required work load in the most efficient manner.

Similar studies are made for the development of power plants, pumping plants, industrial gas plants, and the placing of utilities of all kinds. When the general arrangement has been decided upon by the mechanical and operating departments concerned, the approved schematic plans are further developed by the engi-

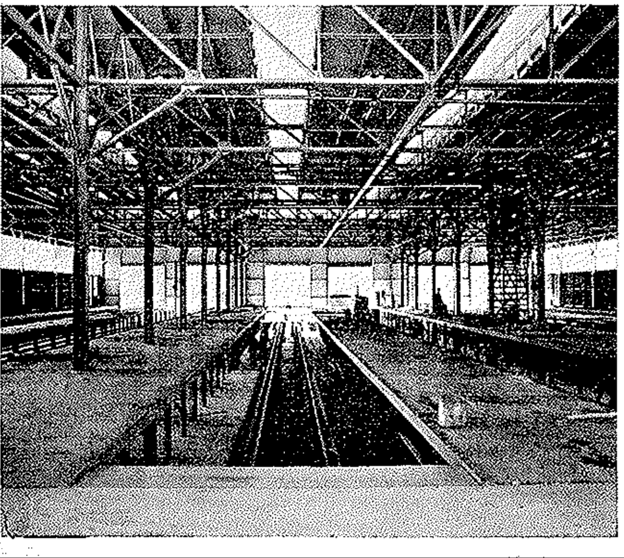


View of the erecting bay of Santa Fe Diesel shop at Chicago with three 1800 horsepower Diesel units over the drop pits. Along the pits are drop tables permitting change of wheels and traction motors.



View of the Barstow Diesel shop during construction.

Interior of new Diesel shop at Barstow. This shop building has six-tracks, each capable of accommodating an entire four-unit Diesel-electric locomotive.



neering department in the way of architectural and structural detailing and also for the contracting and supervision of the construction of the buildings, laying of tracks, and other civil engineering details.

The engineer of shop extensions, meanwhile, writes the specifications, places requisitions for the machine tools, cranes, and other weight lifting or hauling equipment, boilers' and pumps, air compressors, electric generators and other mechanical equipment as required. After the new buildings or additions to existing buildings have been completed, the engineer of shop extensions' mechanical and electrical construction crews install the machine tools and the powerhouse equipment. The equipment is then tested and turned over for operation.

Studies of needed improvements in the rearrangement or additions of existing shop and terminal buildings to permit more economical operation of such facilities are made by the mechanical section; also studies of machine tool operations to determine the need for additional machine tools or machine tools which are more productive and more economical to operate. Recommendations, the result of those studies, appear as items in the annual additions and betterment program.

During the decade after World War I the main locomotive repair shops at Albuquerque, San Bernardino and Cleburne were almost entirely rebuilt and in them were installed large-capacity lifting cranes and other modern equipment. These shops were of inestimable value in repairing the motive power during the period of heavy demands on our transportation in World War II.

It is necessary yearly to augment and revise or replace certain machine-tool facilities on the Santa Fe. That is caused by the normal evolution in shop and maintenance practices, also by the introduction of new phases in railway technology. The advent of Diesel power has necessitated the installation of special facilities in addition to buildings. A new Diesel maintenance shop and auxiliary Diesel facilities recently have been constructed and put into service at Barstow.

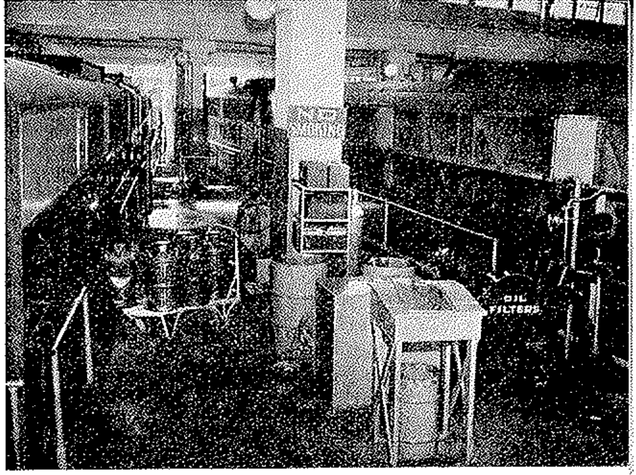
There is no industry at the moment experiencing a greater change in overall concept than America's railways. As the railway is essentially a machine for mass land transportation, and the only proven means of completely and efficiently accomplishing that task, changes affecting it must be on a scale comparably large.

The engineer of shop extensions keeps pace with new machine tools and new methods, particularly Santa Fe mechanical and operating practices. The value of shop machinery and powerhouse equipment in use on Santa Fe premises and the annual expenditure for maintenance of that equipment reach considerable proportions. The construction crews of the mechanical section do the heavy maintenance and repair work on shop machinery and powerhouse equipment such as rebricking of stationary boilers, the renewal of steel smokestacks, overhauling generators, pumps, air compressors, and certain shop piping which reauires heavy or special tools.

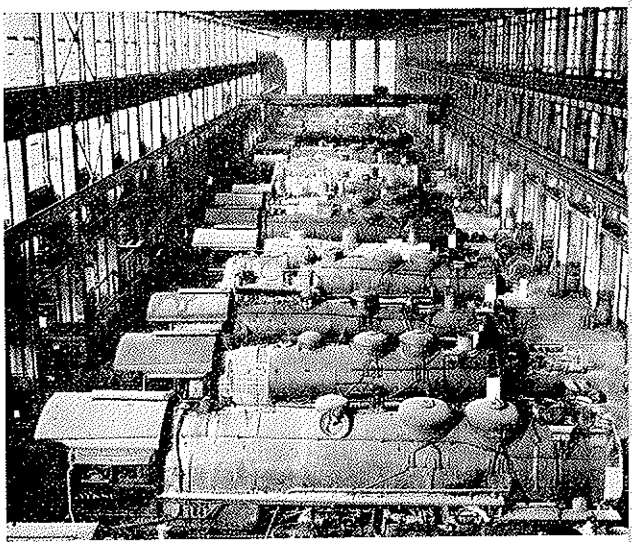
The electrical division of the shop extensions department designs the wiring for electric power and light in all shops, pumping plants, offices and stations and other buildings owned or leased by the Santa Fe. Present installations include 100,000 lighting outlets in the various buildings and approximately 4,000 motors. All electrical installations must be made in accordance with the National Electric Code and certain other Federal, state and municipal regulations. Inspectors working out of the office of the engineer of shop extensions personally examine each installation reporting any defects for immediate correction.

The department also prepares and checks all details concerning contracts for power purchased by the Santa Fe from utility companies, and revises such contracts as new scheduled rates are published from time to time by the utility companies. In addition to that supplied by its own facilities, the Santa Fe purchases power at some nine hundred stations throughout its system lines.

The Santa Fe operates approximately fifty gasoline-electric rail motor cars. These cars supply needed train service on many branch lines at a cost lower than would be possible with the operation of steam locomotives in this service. Gasoline-electric motor cars carry passengers, U. S. mail, express and baggage. They are powered by electric motors supplied with energy produced by generators in each car which in turn are operated by internal combustion gasoline engines. The general supervision of the maintenance of these cars is the responsibility of the electrical section of the shop extensions department.

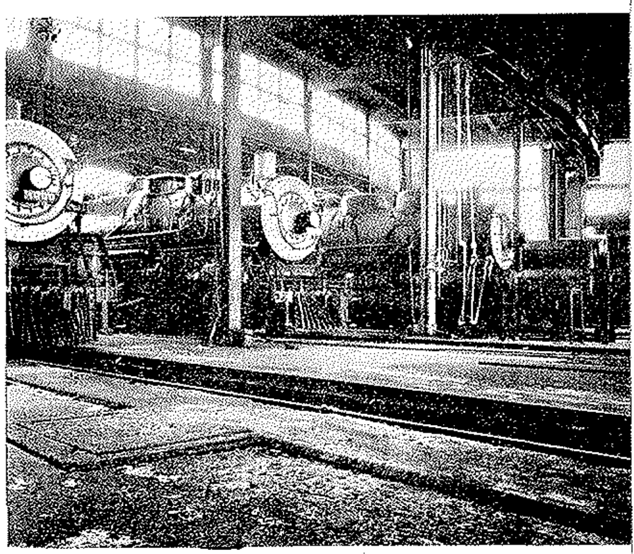


Interior of Diesel shop at, Winslow. From concrete platforms, installed in roundhouse to bring floor up to Diesel floor level, workmen put new oil filters in Diesel unit at right and lubricating oil in unit at left.



General view of erecting floor of Santa Fe locomotive shops in San Bernardino, Cal.

Interior view of Santa Fe roundhouse at Emporia, Kan.



The Fuel Conservation Department

THE conservation of fuel is an important phase of railway operation as expenditures for train fuel top any other single item of operating expense. The Santa Fe expends in excess of $25,000,000 annually for train fuel. If it were not for the scientific efforts put forth to conserve fuel, the figure would he considerably higher.

The Santa Fe's fuel conservation engineer, E. G. Sanders, Topeka, assisted by fuel supervisors — one on each grand division — and six division fuel supervisors assigned to groups of local divisions throughout the system lines, is charged with the conservation of all fuel used by the Santa Fe. That is accomplished by instructing Santa Fe people in the proper usage of fuel and the prevention of fuel waste through any cause. The various fuels used by the Santa Fe include the following:

Bituminous, subbituminous and anthracite coal.

Residue fuel oil for generating steam in locomotives and in power plants, heating plants, and others.

Diesel fuel oil for use in Diesel locomotives and stationary Diesel engines.

Gasoline used in gas-electric motor cars, rail motor cars, stationary gas engines and miscellaneous purposes.

Distillate used in stationary internal combustion engines, heat treating and forging furnaces and weed burners.

Coke used in forging furnaces, general blacksmith forges, and heating roundhouses.

Charcoal used for pre-heating large castings before welding, in tin shop furnaces, and for cooking purposes on dining cars and in Harvey Houses.

Natural gas used for generating steam in power plant boilers, heating plant boilers, heat treating furnaces. firing up locomotives in roundhouses, and for cooking purposes in Harvey Houses.

Since the Santa Fe's fuel conservation department mas organized in 1923, considerable economies have been effected in the matter of fuel consumption.

E. G. Sanders, fuel conservation engineer, with headquarters in Topeka, Kan.

In actual savings, if fuel prices for 1943 had been comparable to fuel prices for 1923, the figure would have exceeded eight million dollars for the single year, 1943. Many factors contributed to that reduction as the fuel conservation department must have the co-operation of other Santa Fe departments. Most of the latter, directly or indirectly, affect the conservation of fuel. Mechanical improvements and innovations also have a direct hearing on fuel savings. Constant vigilance is necessary that maximum efficiency be obtained from fuel consumed.

The members of the fuel conservation department are either experienced locomotive engineers and firemen, or tech-

1923. Freight service	181 pounds per 1,000 grass ton miles.
1943. Freight service	135 pounds per 1,000 gross ton miles.
Net reduction 25.4 per cent.	
1923. Passenger service	17.4 pounds per passenger car mile.
1943. Passenger service	13.7 pounds per passenger car mile.
Net reduction 21.3 per cent.	
1923. Switching service.	160 pounds per switch locomotive mile.
1943. Switching service.	125 pounds per switch locomotive mile.
Net reduction 21.9 per cent.	

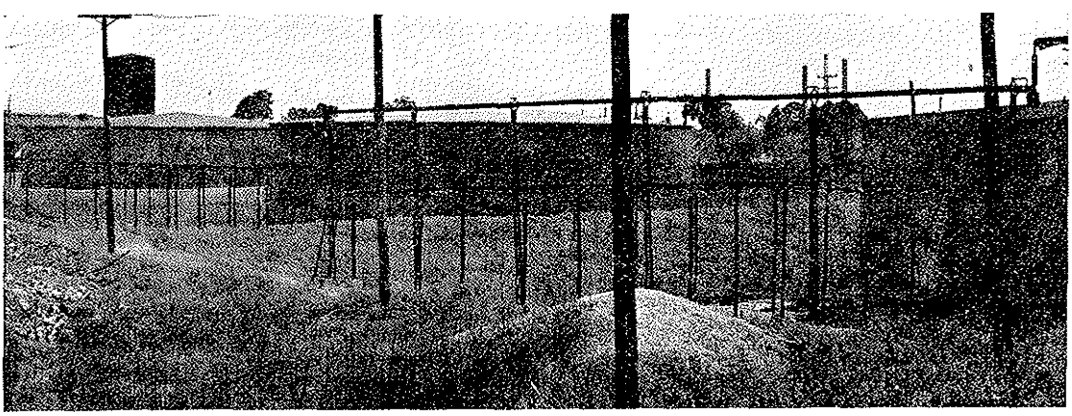
Santa Fe stock coal pile at Argentine, Kan. Automobile on left indicates sire of pile

nically trained men, all of whom are versed in the proper combustion of fuel. It is their duty to instruct new firemen on locomotives and in stationary boiler plants, and, when necessary, to demonstrate to any fireman correct firing methods. They inspect locomotives, reporting defective conditions which waste fuel. They also detect improper practices and conditions and in each instance take necessary corrective action.

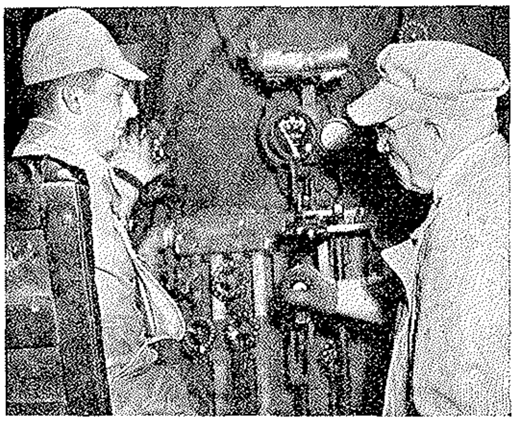
Most Santa Fe fuel is consumed in locomotives and it is a popular conception that fuel conservation rests with the locomotive fireman. The fireman does play an important role but there are many other Santa Fe people who contribute as much toward obtaining maximum efficiency in the use of fuel. Prominent among the latter are locomotive and stationary engineers, water chemists, train dispatchers, and shop, terminal, yard and roundhouse personnel.

Santa Fe enginemen are guided by the Official Instructions for Enginemen governing the Care, Maintenance and Economical Operation of the Steam Locomotive, and Rules and Regulations covering the Care and Operation of Locomotive Oil-burning Equipment, containing precise methods of operating those types of locomotives. Another instruction hook, Rules and Regulations governing Care and Handling of Locomotives by Engine Watchmen, provide for proper care of engines at points where engine crews are relieved from duty. The fuel conservation engineer revises and reissues those books, in conjunction with other interested Santa Fe departments, and Santa Fe people whom they concern must familiarize themselves with all changes.

When the purchase of new locomotives is contemplated, the fuel conservation engineer submits his recommendations in regard to the design of those features which will affect fuel consumption. That includes boiler design and capacity, draft-



Santa Fe oil storage tanks at Argentine. With a few exceptions, all Santa Fe steam freight locomotives west of Kansas City are oil burning locomotives.



One of the principal duties of fuel supervisors is to ride with the engine crews and instruct them in the proper methods of firing and operating locomotives. Here we see D. O. Lloyd, district supervisor, discussing operation of firing valve with V. A. Young, fireman of Argentine.

ing appliances, grate design, and various fuel economy devices.

Santa Fe locomotive firemen, upon entering the service, are regarded as student or apprentice engineers in the sense they are encouraged to learn all possible about the locomotive in their care. An inefficient fireman can waste a great deal of fuel by firing too much fuel resulting in black smoke and excessive carbon, wasting steam through pops (safety valve releases), improper blowing out of boilers, maintaining too low or too high water level in the boiler, excessive use of blow-off, shaking unburned coal through the grates into the ash pan, failure to maintain proper temperature of fuel oil on oil burning locomotives and other negligent factors. Efficient firemen eliminate all those wastes.

Locomotive engineers, improperly operating the locomotive can waste as much fuel as do firemen by improper firing methods. Proper manipulation of the throttle and reverse lever, correct handling of the air brakes, maintaining good lubrication of all moving parts, and proper use of cylinder cocks to relieve condensation from cylinders, will reduce to a minimum the amount of steam required to handle the train and thus conserve fuel. Tests have developed that there is as much as fifteen per cent difference in the amount of fuel consumed by the best and poorest of engine crews handling similar trains under similar conditions. It is one of the principal duties of fuel supervisors and division fuel supervisors to ride with the engine crews and to instruct them in the proper methods of firing and operating Iccomotives.

The condition of the locomotive itself is an important fuel conservation factor. Locomotive defects which increase fuel consumption include: superheaters leak-, ing, leaks in firebox and flues, defective cylinders and valve rings, oil burner defective or improperly aligned, air leaks around fire pan and mud rings on oil burning locomotives, dirty water in boiler, flues stopped up with cinders and slag, and air openings in grates plugged with cinders. Locomotive boiler water improperly treated may result in foaming. The water thus is carried over into the superheater and cylinders. Lubrication is washed off and cylinder packing is damaged.

The train dispatcher, by dispatching trains in a manner to reduce delays, can save considerable fuel. Any unnecessary stops or delays en route necessitates burning extra locomotive fuel to bring the train up to speed and to run off the delay. Slow orders due to track or bridge construction increase fuel consumption. The make-up (blocking plan) of trains at terminals can save or waste fuel in relation to switching operations at stations between terminals.

When locomotives are cooled down at roundhouses and then fired up, from 1,500 to 2,000 pounds of coal or two barrels of fuel oil are burned in the process. By increasing the utilization of locomotives, terminal or roundhouse detention is reduced—a direct fuel saving. Prior to 1923, it required fourteen locomotives to handle one Santa Fe passenger train between Chicago and Los Angeles compared with two steam locomotives or one Diesel-electric locomotive today. The longest distance a passenger locomotive operated was 240 miles as compared with 1,791 miles today (steam—Kansas City to Los Angeles) and 2,227 miles (Diesel—Chicago to Los Angeles). In freight service, nineteen locomotives were required to handle one train from Chicago to Los Angeles (via Amarillo) as compared with seven locomotives today. The longest freight run was 167 miles as compared with 637 miles at the present time (Kansas City to Clovis).

Fuel conservation entails a knowledge of the quantity or value (heat units per pound) of coal used, the adaptability of particular coal supplies to locomotive use, and preferred use in relation to fuel supply, demand and availability. The matter of storage of coal must likewise be closely examined. Steam and Diesel fuel oils receive similar consideration.

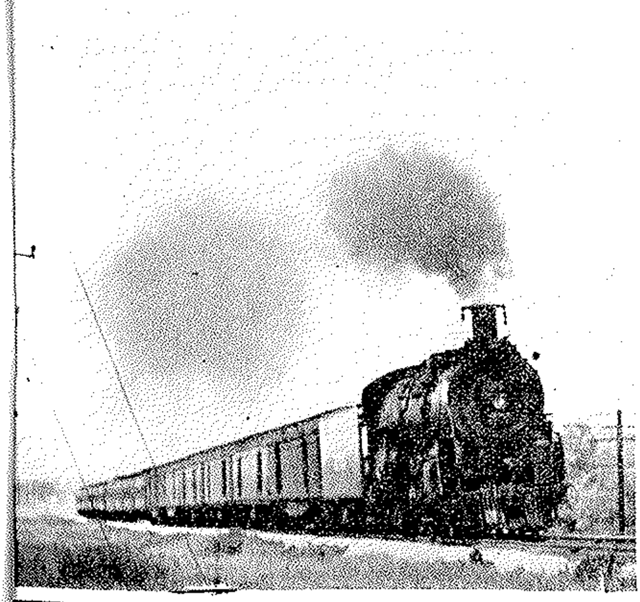
The Santa Fe uses coal on steam freight locomotives between Chicago and Kansas City. That coal (bituminous) is obtained from northern Illinois and southern Kansas' coal fields. Santa Fe steam freight locomotives operating between LaJunta and Denver, and between LaJunta and Albuquerque, burn coal (bituminous) which is obtained from the Trinidad district in Colorado and the Raton district in New Mexico. All regular Santa Fe steam-operated passenger trains are handled with oil burning locomotives. There are a few coal burning passenger locomotives operating between LaJunta and Winslow but they are used on extra passenger trains and as helpers on regular passenger trains. All Santa Fe steam freight locomotives west of Kansas City, except the territory LaJunta-Denver, and LaJunta- Albuquerque, are oil burning locomotives. Coal burning switch locomotives are used at Chicago, Shopton, LaJunta, Pueblo, Raton, Las Vegas, Albuquerque, Gallup and Winslow.

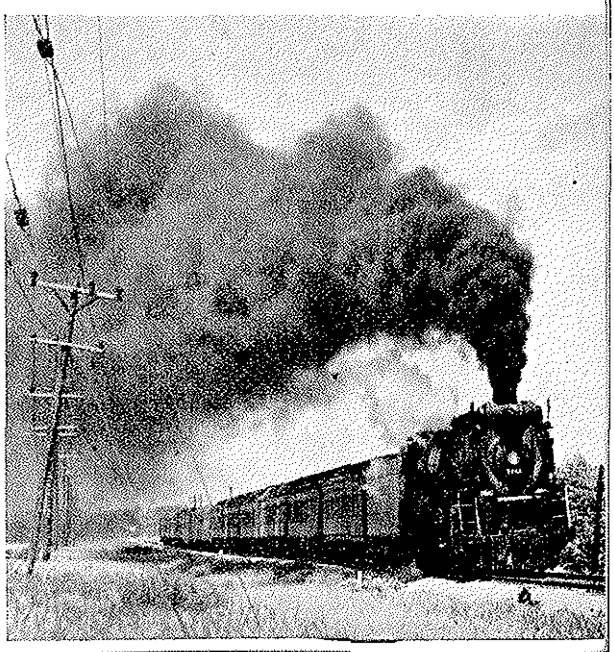
Diesel-electric locomotives are used on streamlined passenger trains between Chicago-Los Angeles, Chicago-Oklahonia City-Tulsa, Bakersfield-Oakland and Los Angeles-SanDiego. Diesel-electric freight locomotives run from Winslow to Barstow and from the latter point to Bakersfield and San Bernardino, also between Chicago and Argentine, Argentine and Winslow, and Argentine and Oklahoma. Diesel-electric switch locomotives are used in nearly all of the principal terminal yards on the Santa Fe system lines. At some of those terminals, Diesel switchers perform nearly all the switching service, steam switch locomotives being used only in emergency operations or when Diesel switchers are out of service. In all yards where Diesel locomotives are used, they are given preference over steam locomotives because of more economical operation.

The Santa Fe's some 241 coal burning steam locomotives use about 95,000 tons of coal per month. The Illinois coal comes from strip mines. For locomotive use, it must be screened, lumps larger than four inches in diameter and smaller than one inch in diameter removed. The screened coal is then washed to remove rocks, dirt and other impurities. Without those procedures, the coal can not be used in locomotives. The coal secured in Kansas likewise comes from strip mines. Here the smaller lumps can be used as this coal has a tendency to form coke and the smaller sizes are not carried through the flues and out the stacks.

The coal obtained from the Trinidad and Raton districts comes from slope mines, mine opening and tipple being located at point of coal vein outcropping. A large portion of this coal is mine run, although considerable modified mine run coal (lumps and impurities removed) also

Below is illustrated the proper and improper firing of steam locomotives. Left— Light haze smoke is the proper way. Right-Black Smoke denotes the improper way.





is obtained as well as various sizes of screened coal—nut, egg and small lump. The Gallup coal is a very satisfactory locomotive coal (subbituminous), although it is a lower rank coal than bituminous, generally containing less heat units per pound. Special screening (lumps over six inches and under one inch in diameter removed) is necessary. Impurities are removed by hand.

The Santa Fe must maintain coal storage piles sufficient for thirty to sixty days use. The fuel conservation department has determined what deterioration, if any, the various coals experience by reason of exposure. Trinidad and Raton coal can be stored without danger of spontaneous combustion. Only screened Illinois and Kansas coal can be stored and there must be good drainage. Gallup coal can not he stored. The Gallup coal mines have always played an important role in Santa Fe operations, beginning with the construction of the Atlantic & Pacific across New Mexico's northern plateau in 1880.

The Santa Fe has some **1,330** oil burning steam locomotives which use about **2,000,000** barrels of fuel oil per month, equivalent to approximately **600,000** tons of coal. Oil burning steam locomotives can burn any type or kind of heavy residual fuel oil (oil left after crude oil has been processed at refinery) provided it is not necessary to heat the oil to temperatures above 180 to **190** degrees Fahrenheit to enable it to burn satisfactorily in a locomotive firebox. Nearly all of the residual fuel oil produced by refineries can be used successfully in oil burning locomotives. Fuel oil storage is maintained at nearly all the important Santa Fe fueling stations. The amount of fuel oil in storage tanks varies considerably depending upon the supply of oil from refineries. When there is a shortage of fuel oil, it is necessary to take oil out of storage to meet current requirements. Usually there are maintained about **3,000,000** barrels of fuel oil in Santa Fe storage tanks, representing a little more than one and one-half months' supplv (war consumption).

The Santa Fe's fleet of Diesel-electric locomotives steadily is increasing and fuel consumption increases monthly. More than **140,000** barrels of Diesel fuel oil are used monthly on the system lines. Of that figure, Diesel freight locomotives use close to eighty per cent, Diesel passenger locomotives eleven per cent and Diesel switchers nine per cent. Those figures will vary as additional Diesel units now on order are delivered and placed in service. Diesel fuel oil for Diesel-electric locomotives is a refined oil meeting rigid specifications in regard to cleanliness, and carbon, sulphur, gum and other content. It also is an oil which burns rapidly and completely in the high speed Diesel engines.

Fuel supervisors and division fuel supervisors often are called upon to observe the performance of various new devices applied to locomotives for trial (in conjunction with test department). Such devices include drafting of locomotives to improve steaming performance, soot blowers, different types of oil heaters, extension movable stacks to raise the smoke above the cab, thermometers to determine the temperature of the oil as fired, different types of oil burners, and spark arresting devices for preventing sparks from being thrown from the stacks.

Fuel tests are frequent. It was necessary at one time to test many kinds of coal in order to comply with the Chicago Smoke Ordinance. Coal from different mines must be tested to determine firing qualities. Such tests involve actual performance tests on the road in addition to test department laboratory analyses made at Topeka. All that enables the fuel conservation engineer to determine which fuel will prove most satisfactory and most economical.

The matter of fuel consumption receives constant attention throughout the Santa Fe system lines. Fuel meetings are held on each local division, the superintendent or master mechanic serving as chairman. Members of the fuel conservation department attend, as well as engineers, firemen, conductors, dispatchers, stationary power plant men, brakemen, car inspectors, hostlers, shop men, track maintenance forces and other Santa Fe people. The meetings are conducted as an open forum, all present encouraged to make suggestions which will contribute toward fuel conservation. Many worthy ideas germinating at these meetings have resulted in appreciable fuel economies.

General Supervisor of Air Brakes

THE general supervisor of air hrakes, F. T. McClure, Topeka, heads that division of the mechanical department exercising control over the operation of air brakes on the Santa Fe system lines. The use of air hrakes is mandatory on American railways. Only by efficient braking methods may speedy runs be attempted and accurate and positive control of trains he obtained.

It is likewise mandatory that Santa Fe locomotive engineers attain proper skill in the use of automatic air brakes. To insure uniformity and skill in braking practices throughout the system, the Santa Fe's air brake department was organized in 1909. Since that year the department has participated in all developments affecting this important phase of railway operation.

When World War II engulfed the United States, the Santa Fe loaned its air hrake instruction car, in charge of J. B. White, assistant general supervisor of air hrakes, to the United States government. Mr. White subsequently instructed various railway operating battalions of the U. S. Army in the use of air brake equipment.

In addition to the assistant general supervisor, the department is staffed by nine assistant supervisors, assigned to designated territories throughout the system lines, who demonstrate to enginemen and others proper methods of road brake practice. They also inspect the maintenance of air hrake and train heating equipment in Santa Fe shops, engine houses and on repair tracks. Those men are skilled in the operation of locomotives and in train handling.

Assistant supervisors of air brakes demonstrate to enginemen and others proper methods of road brake practice. Here we see A. E. Harris, assistant supervisor of air brakes, 3nd C. E. Beltz, engineer, in cab of steam locomotive just prior to departure from San Bernardino.

F. T. McClure, general supervisor of air brakes, with headquarters in Topeka, Kan.

An air hrake and steam heat instructor instructs and demonstrates to repairmen in shops the proper and economical method of making repairs to locomotive and car air hrake equipment, directs the installation and operation of various test racks and testing devices and the proper installation, maintenance and operation of car heating equipment.

Brakes are used to prevent the movement of cars or locomotives when at rest, and, when in motion, to control their speed on descending grades and to stop them when necessary. Those results are accomplished through the friction or holding force resulting from pressing the hrake shoes against the wheel tread or disc faces. That is accomplished by hand power or by air power. Air power is applied through the engineer's hrake valve or by the conductor's valve, the latter located in the caboose on freight trains and on each passenger car.

With the air brake, compressed air effects the brake shoe pressure. The automatic air brake is so named because it is designed to apply hrakes automatically in case air escapes from the system. To accomplish that, an auxiliary air reservoir and other features are added to each car. The automatic air hrake system has the following ten important parts:

A power driven air compressor which supplies air for use in the brake and signal systems.

A governor which controls compressor operation and regulates the air pressure maintained in the main reservoir.

Main reservoirs which serve three purposes: To receive and store the compressed air; to act as a cooling chamber for the compressed air and as a catch basin for moisture and oil which is precipitated from air by cooling; to act as a storage chamber for excess pressure for operating other air using devices without interfering with the brake pipe pressure, and to serve as a backing volume or driving head of excess pressure for the purpose of releasing the brakes and recharging the air brake system.

Two duplex air gauges, one indicating main reservoir and equalizing reservoir pressure, the other, brake pipe and brake cylinder pressures.

An automatic brake valve which regulates the flow of air from the main reservoir into the brake pipe for releasing the brakes and from the brake pipe to the atmosphere for applying the brakes.

A brake pipe (including branch pipe, flexible hose, and couplings) which connects the automatic brake valve, and the conductor's valve, with the triple or other operating valve on each car. Angle and cutout cocks are provided in the brake pipe on each car, the former for opening or closing the brake pipe at any desired point in the train, the latter to cut out individual brakes.

A triple or other operating valve to which the brake pipe, auxiliary reservoir, brake cylinder, and pressure retaining valves are connected, and which controls the flow of air between these parts so as to enable the auxiliary reservoir to be charged and the brakes to be applied and released.

An auxiliary reservoir on each ear in which the compressed air is stored for applying the brake.

A brake cylinder provided with a piston and piston rod connected with the brake levers in such a manner that when the piston is moved by air pressure the brakes are applied.

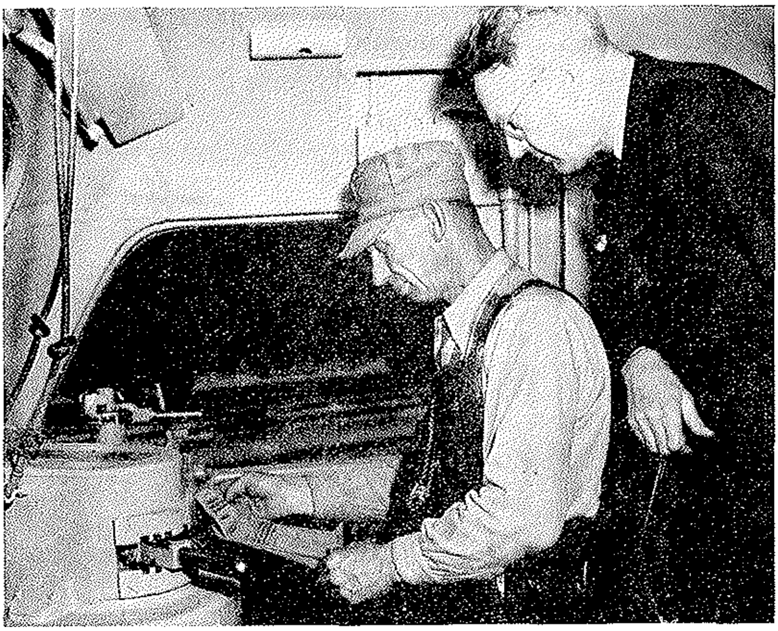
A pressure retaining valve, which in its "turned down" position permits the brake cylinder air to be freely exhausted to the atmosphere; but when "turned up" as in descending a heavy grade, retards the exhaust of air from the brake cylinder down to a predetermined pressure and then retains that amount.

The amount of compressed air is indicated by the air gauges and is stored in reservoirs on the locomotive automatically regulated by a feed valve and passed bv the engineer's brake valve to the brake pipe. A reduction of brake pipe pressure by use of the engineer's brake valve (or broken pipe or burst hose) results in prompt synchronous action of each control valve connected in the train of cars. The control valve is caused to operate by virtue of that property, processed by air under compression, of returning to atmospheric pressure if permitted, or of tending toward equality of pressure throughout any closed system after a previous balance of pressure has been destroyed. The pistons of the internal mechanism of the control valves are caused to operate by an inequality of pressure acting on them, the movement of which permits air pressure to reach the brake cylinders from the storage reservoir on the car. That forces the brake cylinder piston outward, producing a hrake lever operation that presses the brake shoe against the wheel tread with sufficient force to retard and stop the wheel's rotation.

That power of resistance, applied simultaneously to all wheels on each car in the train, makes possible the present-day high degree of efficiency in train speed control.

The brakes are released when the engineer admits compressed air from the main reservoir on the locomotive through the brake valve into the brake pipe, thus increasing the latter's pressure above that remaining in the auxiliary reservoir. That causes the triple valve parts to return to their original position, again opening communication from the brake pipe to the auxiliary reservoir, recharging the latter and making a connection through which the compressed air in the brake cylinder escapes to the atmosphere, thus permitting the release spring in the brake cylinder to return the piston to its former position and releasing the brakes.

The evolution of the air brake is one of the interesting phases of railway progress. The first locomotives and cars had simple hand brakes with iron brake blocks similar to those used on wagons and carriages. The arrangement of a brake beam with two hrake blocks and suitable lever for use of the driver or brakeman was adopted very early by the American railways. The brake beam was of wooden construction. Between 1800 and 1870, some 650 patents were granted in England for various kinds of railway brakes. In the United States, up to 1870, there had been granted 305 patents for railway brakes including five steam, one vacuum, and two air. The first pneumatic brake was patented in England in 1844 and, in 1848, an air hrake was patented having an axle driven pump. In 1855, a chain brake was tried. It consisted of a system of rods and chains continuously connected throughout the train, pulled up by a winding drum on the locomotive.



Assistant supervisor of Air Brakes Harris and Engineer Mattmueller in cab of Diesel locomotive.

The straight air or Westinghouse brake, forerunner of the present-day automatic air brake, was brought out in 1869. It was the simplest and most efficient that had been produced. Its mechanism included a steam driven pump on the locomotive and a reservoir in which compressed air was stored. A pipe line was run through the train and each car was equipped with a simple cast-iron cylinder the piston rod of which was connected to the brake rigging. The system had a serious defect. If the train line parted, an air hose burst, or a rupture occurred in the train line, all braking power was lost—and at a time when such power was most needed.

In 1872, Mr. Westinghouse brought out the plain automatic air brake in which an auxiliary reservoir for storing compressed air was installed on each car, and use was first made of the triple valve which applied and released the brake, and recharged the auxiliary reservoir. If the train pipe broke, the brakes were automatically applied. The present-day automatic air brake is the result of further development of that mechanism.

The mechanical division of the Association of American Railroads and its predecessor, the Master Car Builders Association. since 1870, have made thorough studies of train braking. By 1884, nearly all passenger cars in the United States had been equipped with the Westinghouse automatic brake. The superiority of this brake over all other types was demonstrated in the Burlington Railroad Tests in 1886. A railroad laboratory for air brake tests was established at Altoona, Pa., in 1893. Two years later the laboratory was transferred to Purdue University. In 1926, the A. A. R. in co-operation with the Interstate Commerce Commission inaugurated at Purdue University a very complete series of tests of various types of air brake equipment for Creight service. The rack tests were followed by elaborate road tests. The Santa Fe participated in many of those tests, particularly the road tests held at Eugene, Ore., begun in 1929 and completed in 1931.

Those tests resulted in the adoption of the A. A. R. Specifications for Air Brakes in 1933. The approved freight brake was given the designation "A-R". Additional equipment includes AB-1-B for high speed freight service and AE-4-12 for heavy freight cars. Other important standards are embodied in the A. A. R. Maintenance of Air Brake and Train Signal Equipment on Cars and Locomotives. The A. A. R. Code of Rules for the Interchange of Traffic specifies that air brakes incorporating quick action triple valve, pressure retaining valve, 1%-inch air brake pipe and angle cocks, are required on all railway cars in interchange service. There are further specifications in regard to pressure retaining valves, brake pipes, beams, levers, shoes and other parts of the braking system.

To insure the satisfactory operation of the locomotive brake and signal apparatus, and to guard against delays caused by failures, the incoming engineman is instructed to make a thorough inspection, reporting any needed repairs. The outgoing engineman likewise before leaving the vicinity of the roundhouse must determine whether the equipment is in proper condition to make the trip. Maximum pressure is pumped up in time to make all necessary tests without causing a train delay. That involves determining that the air compressor, the source of supply for the air brake, air signal and various other air-using devices on the locomotive are in condition to provide an ample supply of air. Main reservoir pressure is utilized for operating the bell ringer, sanders, ash pan slide cylinder and pneumatic reversing gear, and the enginemen must, from time to time, note the increased compressor labor necessary to operate those devices, and if the labor is abnormal, leaks should be located and reported. The engineman also must determine that the devices for regulating all pressures are properly performing their functions, that the brake valves work properly in all positions, and that the water has been drained from the air brake system.

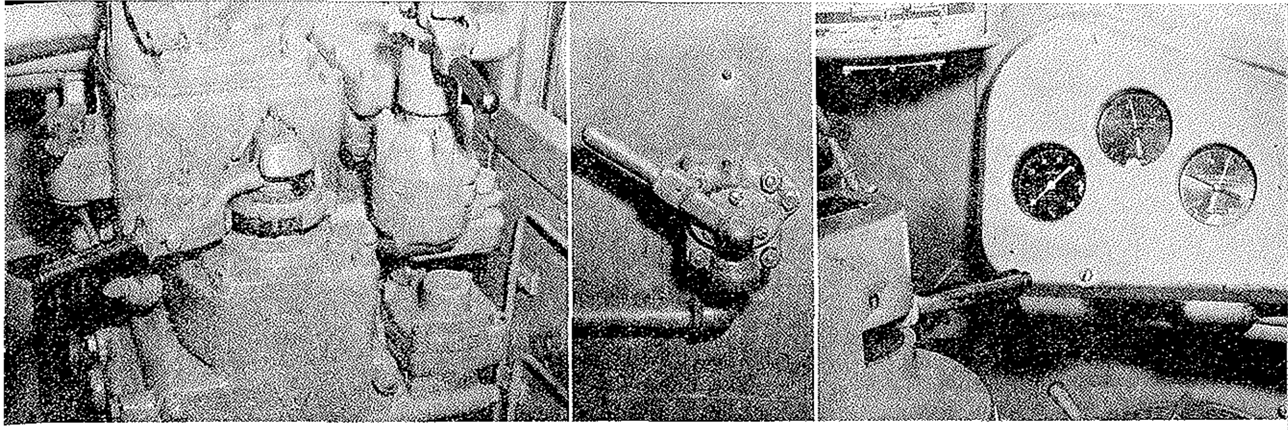
Compressors must be tested for capacity by orifice test before departure from roundhouse each trip. Each main reservoir, before being put into service, and at least once each twelve months thereafter, must be subjected to hydrostatic pressure not less than twenty-five per cent above the maximum allowed air pressure. Hydrostatic test is applied to the main reservoir at the same time the hydrostatic test is applied to the boiler. The entire surface of the reservoir is hammer-tested each time the locomotive is shopped for general repairs, but not less frequently than once each eighteen months. The air gauges, which are located so that they may be conveniently read by the engineer from his usual position in the cab, must be tested at least once each three months and also when any irregularities are reported. The air gauges are compared with an accurate test gauge or dead weight tester and gauges found incorrect are repaired before they are returned to service.

The distributing or control valves, reducing valves, triple valves, straight-air double-check valves, and dirt collectors are cleaned as often as necessary to maintain them safe and suitable for service, hut not less frequently than once each six months. The date of testing or cleaning and the initials of the shop or station at which the work is done is legibly stenciled on the parts or placed on a card displayed under glass in the cab of the locomotive. Foundation brake gear must be maintained in safe and suitable condition. Levers, rods, brake beams, hangers and pins must be of ample strength and must not be fouled in any way. All pins must be secured with cotters, split keys or nuts. Brake shoes must be properly applied and kept approximately in line with the tread of the wheel. No part of the foundation brake gear of the locomotive or tender may be less than 2½ inches above the rails.

Leakage from main reservoir and related piping shall not exceed an average of three pounds per minute in a test of three minutes' duration, made after the pressure has been reduced forty per cent below maximum pressure. Brake pipe leakage may not exceed five pounds per minute. Brake cylinder leakage test is made with a full service application from maximum brake pipe pressure, and with communication to the brake cylinders closed, the brakes on the locomotive and tender remaining applied not less than five minutes.

An important test is made when the engine has been coupled on and a train is preparing to depart. Inspectors request the engineer to apply the brakes and then go to each car in the train and observe the piston to see that the brake is set. When the last car is reached, if the brakes are set properly, the inspector gives a signal to the engineman to release the brakes and then examines each car to see that the brakes release properly. If all brakes functioned properly, an air brake clearance card is given the conductor and each engineman, each of whom must have a copy before departing. The test also must be made when changing crews or the engineman handling the brakes. Detailed instructions in regard to use of air brakes on trains operated with more than one locomotive, as well as other operating department rules in relation to the air brake, are carried in the Santa Fe's important Rules and Regulations, Operating Department.

Braking force necessary to stop a car is measured by the car weight, the speed and the grade. While the hrake holds alike with the same shoe pressure and speed, loading a car increases the distance required for stopping it and the use of more of the possible holding force to keep it from increasing in speed down a grade. The effect of that is in proportion to the increase in weight. The brake on a car weighing 30,000 pounds empty has twice as much work to do when the car carries a load of 30,000 pounds; three times as much when the load is 60,000 pounds. Should the engineman find that he is unable to operate the train brakes from the locomotive, he immediately calls for brakes, in line with operating de-



Close-up views of, left to right, brake valves in Diesel locomotive; freight conductors' brake valve, and air pressure gauge in cab of freight Diesel.

partment rules. Trainmen, upon hearing such signal, immediately open wide the conductor's valve, keeping it open as they proceed to set hand brakes.

The general supervisor of air hrakes and his staff work closely with other branches of the Santa Fe's mechanical department. Efforts are co-ordinated with the road foremen of engines and the test department in various locomotive, train and other operating tests. The educational phase of the general supervisor's responsibility is closely allied with train operation in that it directly affects firemen and engineers.

Monthly statements of local division freight train breaks-in-two account failure of coupler or draft gear are issued by the general supervisor from data compiled by master mechanics. Such statements embody the cause of the train partings segregated as to knuckles opened, broken knuckles or pins, rivets or yokes, broken couplers, carrier irons, air hose, timbers, draft gear, air applied from rear, improper handling or undesired emergency. Total trains parted, freight trains run and percentage to trains run are shown; also freight car miles traveled and freight car miles per train parted. A comparative statement of percentage of decreases or increases also is prepared in relation to the above report.

The general supervisor of air brakes also compiles by divisions a comparative statement of pairs of wheels slid and single wheels cracked (freight), and pairs of wheels slid and number of wheels brake-burned (passenger).

At the time of employment, a Santa Fe fireman is given a First Year book of queslions and at the end of his first year's service Ire is required to pass a written examination thereon. After successfully passing the First Year's examination, he is given the Second Year's book. After successfully passing that a year later, he is given the Final examination book. The fireman is required to pass a written and oral examination on the Final when he has had sufficient experience with the Santa Fe to make him eligible for promotion, according to rules and agreements, to locomotive engineer.

The general supervisor of air hrakes plays an important part in those procedures. An instruction car is used by the department to aid in the educational program and all supervisors are ready and eager to assist enginemen to a proper knowledge of the mechanical features of air brakes and to acquire skill in the application of braking power.

Many details enter into the braking of trains and there are voluminous instructions and recommendations to cover circumstances and phases of the subject. The type of train, numher of cars, tonnage, types of cars, the locomotive employed, the terrain, speed, curves, gradients — many factors create conditions which must be met in a manner which will in passenger service safeguard, passengers and equipment. There are a great many additional problems in freight train operation, one being slack action. which can be alleviated, if not eliminated, by proper manipulation of the locomotive and proper handling of train brakes. The general supervisor of air brakes imparts means for control of all those factors to the end that Santa Fe enginemen may properly apply the scientific braking knowledge which is at their disposal.

The fundamental and indispensable requirements of good braking are the skill, the aptitude, and the ability of the engineer. Such qualifications are gained only through proper training and experience.

Car Lighting and Air-Conditioning Engineer

CAR lighting and air-conditioning engineer, A. E. Voigt, Topeka, with a force of some two hundred Santa Fe men and women, assumes responsibility for all electric power on the Santa Fe's movable equipment. This includes passenger car lighting, thermostatic heat control, ventilation and air-conditioning. The department also supervises and maintains radios, electric dishwashers, annunciators, electric razor converters, pressing irons, electric door openers, and other features of Santa Fe passenger equipment—all contributing to the comfort and well-being of Santa Fe patrons.

There is scarcely anything which can be obtained in a modern hotel which the Santa Fe does not furnish on its through passenger trains. Inspection and repair are continuous so that the many innovations provided for Santa Fe patrons are available at all times. Such facilities often have delicate mechanisms and it requires alertness and skill to keep them in good operating condition.

Car lighting and air-conditioning forces are spread throughout the Santa Fe system lines. Chicago, Kansas City, Los Angeles, Richmond, and Galveston have the larger forces consisting of machinists, sheet metal-workers, electricians and others, who inspect and repair Santa Fe passenger equipment prior to its departure from those terminals. Inspectors ride trains when necessary and are stationed at various points along the line to handle emergency repairs en route and to maintain local equipment. Other forces are stationed at passenger repair shops.

The Santa Fe has the distinction of having operated the first axle lighted passenger equipment in railway service. On November 4, 1897, the Santa Fe equipped chair ear No. 1403 with the National Car Lighting Company's axle generator, belt propelled equipment, 32 volt. In the early years when American trains first attempted night operations, passengers brought their own candles. The railways later provided the candles, also glass draft shields. Oil lamps were introduced in 1850; gas, around 1875, the latter continuing in use after the turn of the century. The Pintsch gas, acetylene

A. E. Voigt, car lighting and air conditioning engineer, with headquarters in Topeka, Kan.

gas, and gasoline vapor systems were used. Experiments in electric lighting began in the early 1880's.

Lighting current is supplied modern Santa Fe passenger cars by a generator propelled by a pulley on the car axle, in conjunction with an automatic regulator and storage batteries. This equipment is a power unit within itself automatically controlled. It must function day and night without supervision. Current is generated while car is in motion and is stored in the batteries which range in capacity from 200 ampere hours, in use on baggage cars, to 1,000 ampere hours as used in air-conditioned coaches, chair, lounge, and other types of cars. The batteries, which are sixteen cell, 32 volt, and weigh from 1,600 to 3,400 pounds, take care of the car's lighting needs prior to starts and when car is standing still. The first electric car lighting equipment had a capacity of only one kilowatt. Today there are in use on railway equipment of twenty to thirty kilowatt. The Santa Fe uses only ten kilowatt because most of the power for its air-conditioning is steam instead of electricity.

The Sauta Fe was the first railway to install electric markers on the rear end of its passenger trains. That was in 1903, when the use of oil was universal. The Santa Fe is today the only railway using electric markers on the rear of all its passenger trains. The Santa Fe likewise is the only railway which continued the use of hard rubber battery jars without interruption. In the case of locomotive headlights, maintenance of which is a shop's or roundhouse responsibility, electric current is supplied by a small turho-generator located on and operated by steam from the locomotive's boiler. Diesel headlights are powered by an auxiliary generator and batteries.

Modern air-conditioning in use on America's railways is divided into three general groups or systems: (1) Steam ejector, the method used by the Santa Fe; (2) ice activated, refrigeration being obtained through the melting of ice; (3) mechanical compression, the use of a compressor. The third group is subdivided into four additional groups according to the method used in driving the compressor. These four groups are: Mechanically-driven comnressor, direct from axle through a magnetic slipping clutch so as to obtain constant speed of the compressor regardless of the train speed; electrically-driven compressor, power being secured from generator driven by car axle in conjunction with a storage hattery; internal combustion engine drive; head-end power drive, as in articulated Diesel trains.

Several systems are employed for transmitting power from the truck axle to the generator or to the cooling equipment—belt, gearing and drive shaft. Other factors which vary are types of control, which are manual, semiautomatic and automatic; filters, which embody the important "cleanliness" feature of air-conditioning, and which likewise are of various kinds; ventilation and circulation, which embrace factors of air exhaust, percentage of clean air added, location of cooling units and design of air ducts, vanes and grilles; heating, which may be incorporated in the air-conditioning system (the Santa Fe uses steam for both heating and cooling). In the mechanical compression system, Freon, a refrigerant (dichlorodifluoromethane, CCl_2F_2) is in general use.

Air-conditioning generally is recognized as a cooling process. That is not altogether correct. In the Santa Fe's adopted air-conditioning methods, the air is filtered, then cooled, dehumidified, and washed or heated as desired to meet summer or winter temperatures. The ice method of air-condition-

The Santa Fe was the first railway to install the steam ejector air-conditioning system in service. The above scene in the club lounge car on the 41 Capitan reflects the comfort, cleanliness and well being which this method provides Santa Fe patrons.

ing can be installed at least cost and it is reliable and satisfactory where the cooling season and the runs are short. It is most expensive to operate, however, where the seasons and runs are long and outside temperatures are high. Delays to trains also are experienced in reicing cars en route.

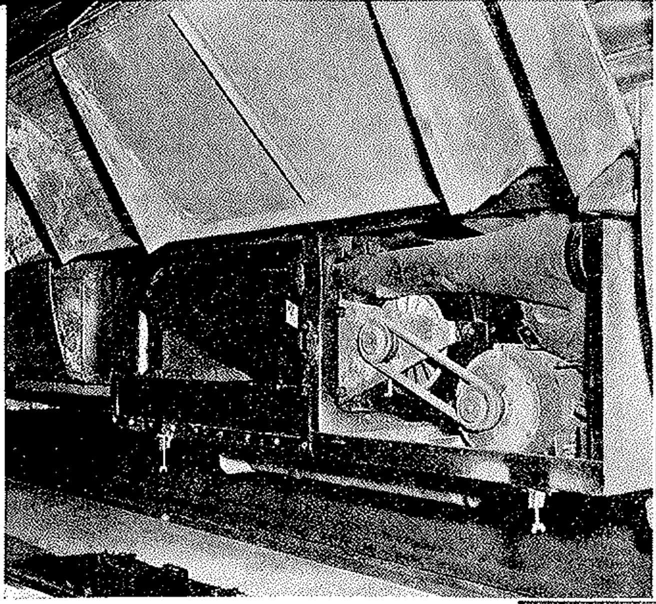
The Santa Fe chose the steam ejector system as best suited to its needs. It was the first railway to install this equipment in service. With the steam ejector system, 185 pounds of steam per hour is required where six-ton refrigeration (equivalent to making six tons of ice per hour) is used, and 3.75 of horsepower for driving four fractional horsepower motors for two water pumps and two blower fans. It requires less steam to cool a car in summer than it does to heat it in winter because there is not so much loss from condensation. The steam, which is the bulk of the power in the Santa Fe's air-conditioning system, is taken direct from the boiler of the locomotive through the trainline (steam pipe) which furnishes steam in the winter for heating.

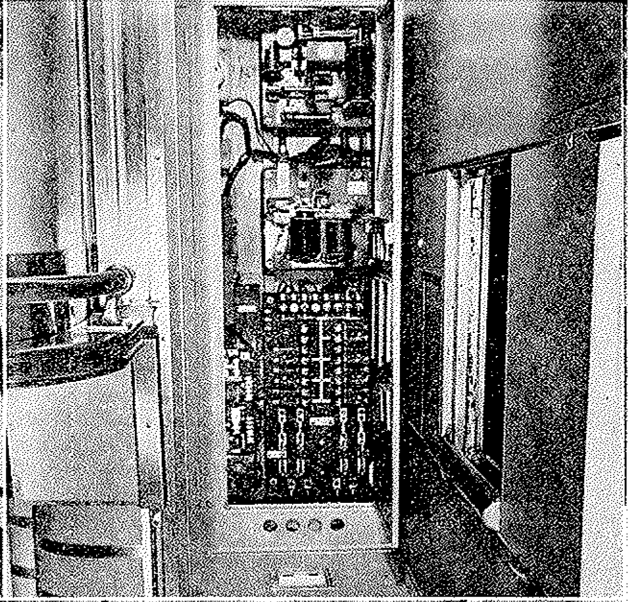
The principle of the steam ejector air-conditioning system consists in creating a vacuum over water. That is accomplished by the use of a centrifugal pump through a water purge and a steam ejector. The system utilizes a well-established law that a definite quantity of heat is required to evaporate a pound of water. The normal boiling point of water at sea level is 212°, but when 29.55 inches of vacuum are secured over the water, the water will boil or evaporate at a temperature of fifty degrees. Removal of atmospheric pressure lowers the boiling point according to the amount of pressure retained on the water.

The temperature of the human body is kept constant by evaporation. In the steam ejector method of air-conditioning we have the boiling or evaporation of water resulting in cold water. In the procedure, close to a perfect vacuum is created, and water-temperatures as low as 45° and 50° Fahrenheit are obtained. The water gives up its heat, or is reduced in temperature by evaporation; it is then pumped into the air-conditioner. The latter consists of coils with fins similar to the construction of an automobile radiator. Outside air having passed through an oiled filter where all dirt is removed, is drawn through these coils, where it is instantly cooled by the cold water in the coils. It then enters the car, clean and cool, through ducts. Steam from the locomotive is used to carry the vapor away from the cold water while it is giving up its heat. This heat is drawn into the condenser coil and with the steam is condensed by means of a spray of water (spraying secures capacity) which is pumped over the coils. A blower fan delivers to the outside the heat which is given up by the water and the steam. The relative humidity of the air in the car is reduced by the 50° water passing through the coils through which the air is drawn, resulting in condensate accumulating on the coils. Condensate on the fins of the cooling coils also results in the air being washed when it was drawn through them.

In Santa Fe air-conditioned cars, seventy-five per cent of the air is recirculated and twenty-five per cent is drawn fresh into the car. That results in constantly changing air without drafts and other bothersome conditions. There is also a fresh air damper so arranged that it is possible to draw in 100 per cent fresh air when a complete change of air in the car is desired. In the air-conditioning equipment, where the cold water coils are located, a fin type coil, thermostatically controlled, has been placed. That heats or tempers all outside air which is drawn into the car during the winter months providing uniform heating. The air-conditioning system thus supplies clean cool air in summer and warm clean air in winter.

The old method of railway car ventilation was accomplished by use of exhaust fans, which resulted in a lower air pressure within the car than without. Dirt could come in. With the present method, a pressure is built up within the car, slightly greater than that without, and no dirt may enter. There are five different types of air delivery to railway cars: inside center duct; double outside ducts with outlets in each duct not directly opposite those of the other duct; single outside duct; double end bulkhead; center bulkhead. The types are listed in the order of their effectiveness. All the lower berths in Santa Fe standard sleeping cars are equipped with ventilation which can be controlled by the occupant, reducing or shutting off entirely the amount of air delivered into the berths. The Santa Fe installed the first lower berth air-delivery grilles used, through which fresh and recirculated air was delivered to the berth subject to the control of the occupant. That installation was first made in 1935. Prior to that, a separate blower through which recirculated air only was delivered to the lower berth and fans in the berth's curtains





No single factor has contributed more toward the pleasure and comfort of travel, summer and winter, than the modern air-conditioning of railway cars. Here are pictured some of the component parts of the Santa Fe system.

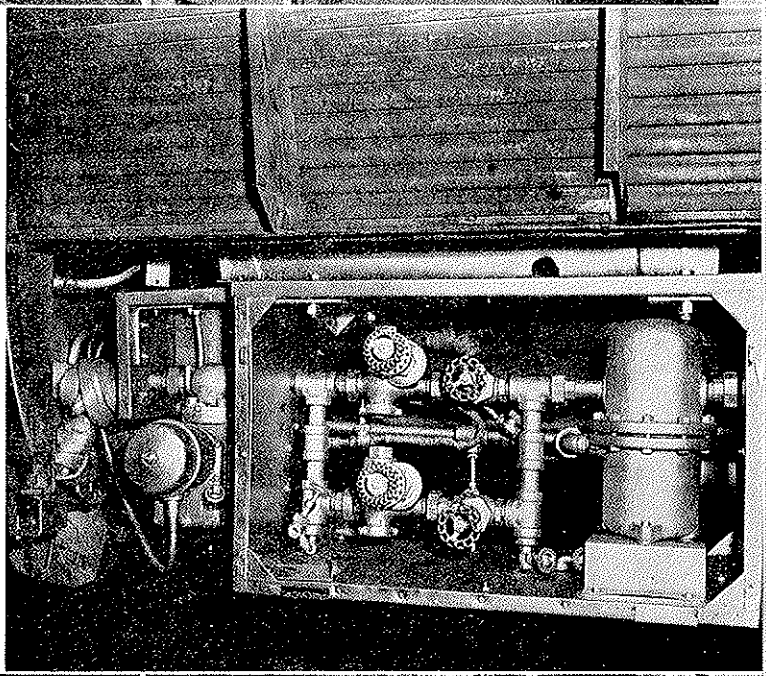
Upper left—Part of refrigeration unit showing fan belt.

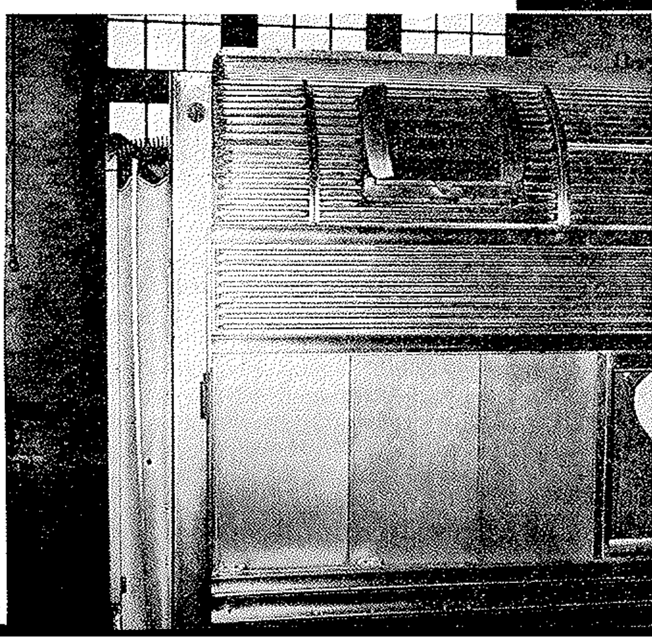
Upper right—Recirculated air grille and power switchboard and air conditioning control.

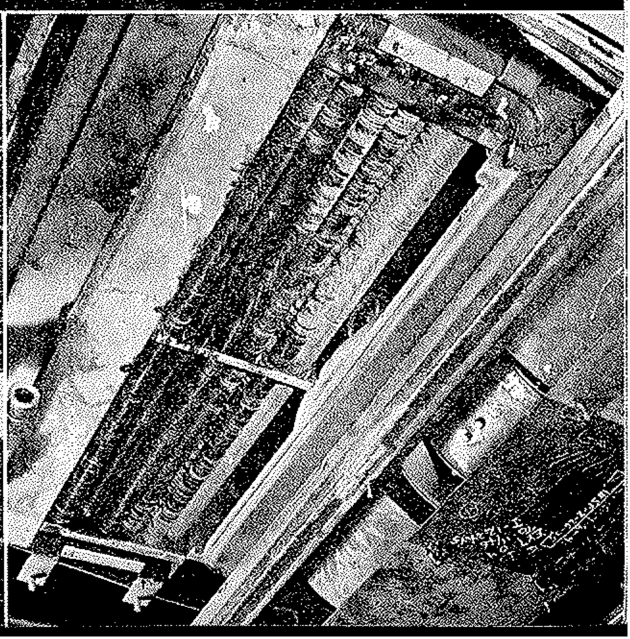
Center—Part of refrigeration unit showing valves.

Lower left—Fresh air intake section of air conditioning unit.

Lower right—Air conditioning unit located in lounge ceiling above the bar.







through which recirculated air was delivered to the occupant were in use. The Santa Fe was also the first railway to install fresh air damper controls (1935) that permitted the damper to be set for 25, 50, 75 or 100 per cent fresh air.

The Santa Fe's application of modern air-conditioning to a number of passenger cars in actual service antedated similar undertakings by all other railways. In 1911, the Santa Fe installed the Duntley Air Washer in eight diners, the first in long distance train service. In 1914, fifteen additional dining and ten buffet cars were equipped, continuing in Santa Fe service until 1926. Those applications consisted of a motor, driving a spray wheel, the latter partially submerged in ice water. Fresh air was drawn through the spray and delivered into the car by means of a fan and air ducts along the deck of the car. This system lacked capacity but was successful inasmuch as it washed the air and lowered the temperature of the car a few degrees. In 1926, consideration was given the possible application of a 30-ton compressor in a Santa Fe baggage car to cool three or four cars in the train. The plan was not flexible due to the necessity of having to keep certain cars together in a train; also the equipment would have occupied about one-half of a baggage car. In 1929, the Santa Fe test department investigated the use of dry ice hut its use was not adopted.

Santa Fe diner 1418 was equipped in July, 1930, with the Carrier Engineering Corporation's ammonia compressor system, the compressor pumps and fans being driven by the standard 32-volt system used on the car for lighting purposes. This car was the second air-conditioned car of larger capacity placed in commercial service in the world and was the first to have air-conditioned equipment operating at all times—with car in fast or slow motion or standing still. The power supply for diner 1418 consisted of two 7½ k. ~ 32-volt generators, driven by gears from the car axle, and a 2,250-ampere hour battery.

In view of its widespread use, it is difficult to realize that modern air-conditioning of railway cars is a product of the present decade. No single factor has contributed more toward the pleasure and comfort of travel, summer or winter.

In the vapor system of heating used on Santa Fe passenger trains, the live steam from the train pipe is converted into vapor through a vapor regulating valve and only vapor is supplied the radiating pipes of the car. A pressure reducing valve on the locomotive reduces boiler pressure to the required train line pressure as indicated by the steam heat gauge in the cab. On Diesel locomotives equipped with steam generator, the steam pressure is regulated at the generator by the pressure switch. The required steam train line pressure is dependent upon the weather and the number of cars. The reduced steam pressure flows back through the steam train line, under the cars, which are connected by suitable flexible metallic conduits and steam couplers. At each end of the car an end valve is provided in the steam train line. That shuts off the steam when necessary in switching cars and closes the train line at the rear end of the train.

Branch pipes extend under each passenger car from the steam train line to the vapor regulators. The regulators reduce the train line pressure to atmospheric pressure for use in the heating coils inside the car, the temperature of this steam being about 212 degrees. The flow of vapor into the heating coils is controlled by vapor cut-out valves. These vapor cut-out valves are of two types, manually operated and magnetic Heating coils are arranged along the side walls within the cars, generally called "floor heat radiators." The heating coil located adjacent to the cooling coil on the cars that are equipped for air-conditioning is generally referred to as the "overhead heat." In cars with manually controlled vapor system the hand operated vapor cut-out valrc may he opened or closed as required for proper temperature regulation. In cars which are thermostatically controlled, adjustment of temperature regulation is made on an electric panel. The thermostatically controlled vapor system automatically maintains uniform temperatures according to the thermostatic setting. It is a Santa Fe practice to place, in the control panel cabinet of each car, printed instructions for operating the heating and cooling system of that car.

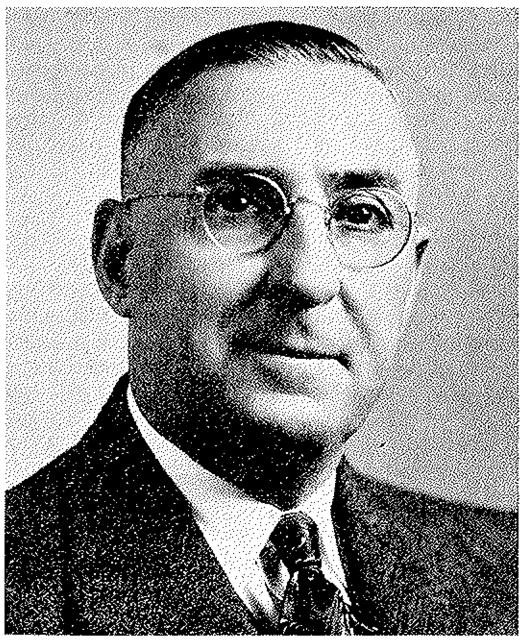
The air-conditioning systems on Santa Fe cars are checked and overhauled each year. Record is kept of overhauling dates and a monthly report, prepared and furnished by the car lighting and air-conditioning engineer's staff to all inspectors of the department and to Santa Fe terminals, states which part of the equipment should he handled. Each through inspector of the department and the foremen at terminals render a daily report of the condition of cars upon reaching their terminal and the repairs furnished each car. Monthly reports received from passenger repair shops contain similar information. During the summer months, daily reports of air-conditioning irregularities are furnished and promptly followed up to insure that all have been corrected.

The car lighting and air-conditioning engineer maintains a card historical record of all batteries, generators, regulators and air-conditioning equipment on Santa Fe passenger cars; also batteries on Diesel locomotives, gasoline-motor cars and Santa Fe outfit cars (track and other work crews on line), The record enables the department to follow up that equipment to see that it is given attention at the proper time, safeguarding the equipment and forestalling possible failures. It also eliminates excessive failures and reduces losses of generator belts and lengthens battery life through proper maintenance.

The car lighting and air-conditioning department handles electrical features, lighting, heating, ventilating, cooling, and other power usages of railway cars or trains parked during conventions. That often involves a considerable task. There are other special trains which may be parked in which it is expedient that all service facilities function properly — presidential specials, tours of foreign dignitaries, movie premieres and other events. The department's inspectors and technicians are instructed in regard to the handling of those special movements, either riding the trains or inspecting and servicing them upon arrival at terminals.

General Boiler Inspector

ALL locomotive and stationary steam boilers, tanks and pressure reservoirs; hoiler washing plants and boiler washing and cleaning methods; tools and appliances used in boiler and related work; fireboxes, flues, staybolts and spark arresting devices — the care, maintenance and performance of those Santa Fe facilities and tools, and inspection rules pertaining to power plants, boilers and pressure tanks, are particular responsibilities of H. H. Service, general boiler inspector, Topeka. Throughout the system lines, assistant general hoiler inspectors assume those responsibilities on grand division territories.



H. H. Service, general boiler inspector, with headquarters in Topeka, Kan.

In detailed application, boiler inspection work involves many related matters. Checking the proper filling of boilers to a safe water level preparatory to firing up, checking the true condition at time fires are started and insuring that correct procedures are followed; noting water glasses and gauge cocks to determine if operative; cab cards, that they are correctly issued and that there are no violations of Federal laws; the terminal blowing down of boiler waters of locomotives in roundhouses; defective conditions of cab stands, cabs, cab braces, windows, studs, aprons, handholds, steps, decks and other locomotive features—all are reported in relation to safety appliance standards.

The general boiler inspector maintains Santa Fe system records of inspections and repairs made on stationary and locomotive boilers, flues, staybolt and firebox plate performance and related matters, making comparison from time to time by means of these records to determine the performance of such parts. There are examinations of low water cases and detailed inspection with Federal inspectors with final reporting of conclusions. Federal inspectors' monthly reports of defects noted are checked and analyzed and annually are compared with twenty other Class One railways as to the items most frequently reported by chief inspector of Bureau of Locomotive Inspection.

It is an important function of the general boiler inspector to insure that the Santa *Fe's* Instroctions to Enginemen governing the Care and Economical Operation of Steam Locomotives is complied with insofar as care of the locomotive boiler is concerned; that proper application of water and blowing out of water is not abused whereby strains and stresses result in the boiler. When such abuses are found they are brought to the attention of the master mechanic. That procedure likewise applies to power plants.

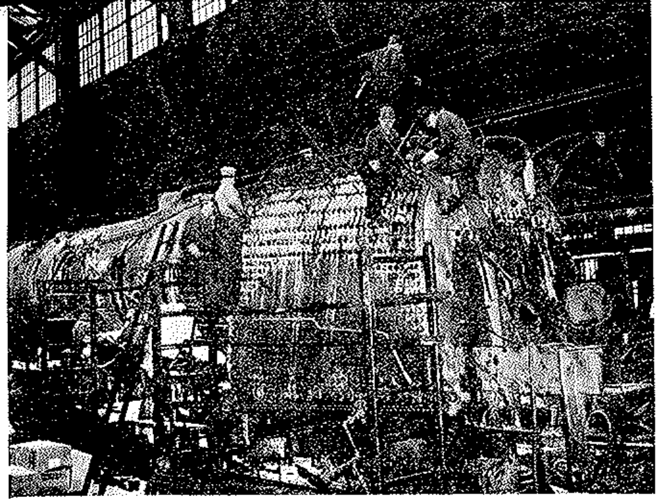
Building, repairing and caring for the locomotive hoiler are important procedures in railway operation. Boilers used in American locomotives are of the internal firebox, straight fire-tube type, constructed with a cylindrical shell containing fire tubes or flues. There is an enlarged back end for the firehox and on the front an extension end or smokehox with a stack overhead. Boilers having a cylindrical shell of uniform diameter are known as "straight top"; those with a conical or sloping course of plates next to the firehox and tapering down to the cylindrical courses are "wagon top"; those having one or more cylindrical courses between the firebox and the sloping course which tapers on the top and sides to the diameter of the main shell are "extended wagon top"; those having one or more cylindrical courses between the firebox and the sloping course and a conical connection course which tapers to the diameter of the main shell are "conical". A boiler having a firehox with a transversely arched crownsheet, supported from the roof sheet by stays or staybolts set on lines that are radii of curvature of the inner or outer sheets, is termed a radial-stay boiler. With most boilers the crownsheet of the firebox is supported by a number of rods or stays passing through the roof sheet and riveted over. Locomotive boilers are made entirely of steel. Staybolts and stays are made of iron.

There are three common designs of fireboxes in general use: The narrow deep firebox, which is between the frames and extends below the top frame rails; the semi-wide shallow firebox which rests on top of the frames and extends to the outside edges of the frame rails; and the wide firebox type having a firebox wider than the frames and extending outside the frame rails on both sides, and resting on top of the frame rails, or expansion brackets which are secured to the top of the frames.

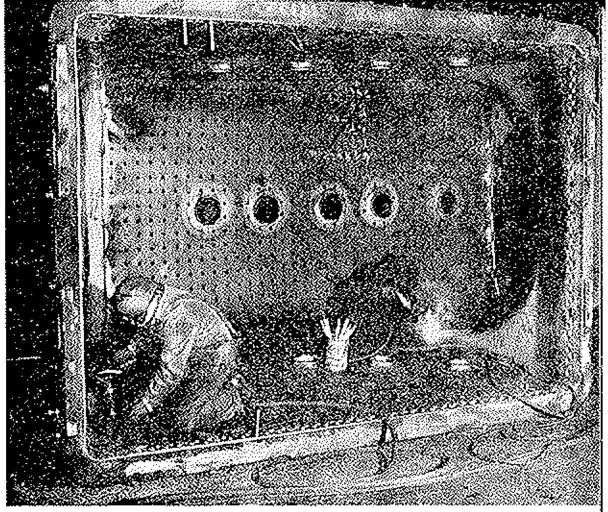
The combustion chamhcr for large locomotives mas originally introduced for the purpose of providing increased firebox area for combustion purposes. Such chambers have been provided on Santa Fe locomotives of the 3700. 3751. 3765, 3776, 3800. 5000 and 5001 classes, the length of combustion chambers varying from forty-two inches to sixty-four inches on those classes. A few installations have been made on the Santa Fe's 3400, 3450 and 4101 classes. In addition to allowing for shorter flues, the combustion chamber's firebox sheets' heating surface is vastly more efficient than the increased length of flues would be if the combustion chamber were not used.

When the crown sheet or firehox sheets are not covered with water, they become overheated very quickly with a hot fire in the firebox. If water is not maintained over the crown sheet and the sheet becomes overheated the fire must be put out or deadened at once and the boiler cooled down before cold water is forced into it. Sudden changes in temperature set up destructive strains in the boiler. The prevention of destructive strains. and stresses or reducing their amplitude is particularly important, the life of a locomotive boiler or firehox depending largely on the care it receives. When steam is generated in the boiler to 200 pounds, the boiler expands nearly one inch. Strains and stresses are thus set up. It is very important that temperature changes be affected slowly, thus reducing uniformly the stresses and strains throughout the entire boiler.

The locomotive's firebox sheets and flues constitute what is known as the heating surface. The heating area of the firebox plates is only five per cent of the flue heating surface but the firehox heating area generates about forty per cent of the steam. The boiler shell is provided with a steam dome on the top which forms a chamber where steam may free itself from the water in the boiler before passing through the throttle on its way to the cylinders. Safety valves are provided for the purpose of preventing the steam pressure rising above that specified for the boiler. When the throttle is opened, steam travels



Topeka shopmen working on shell of locomotive.



Workmen repairing firebox and combustion chamber at Topeka shops.

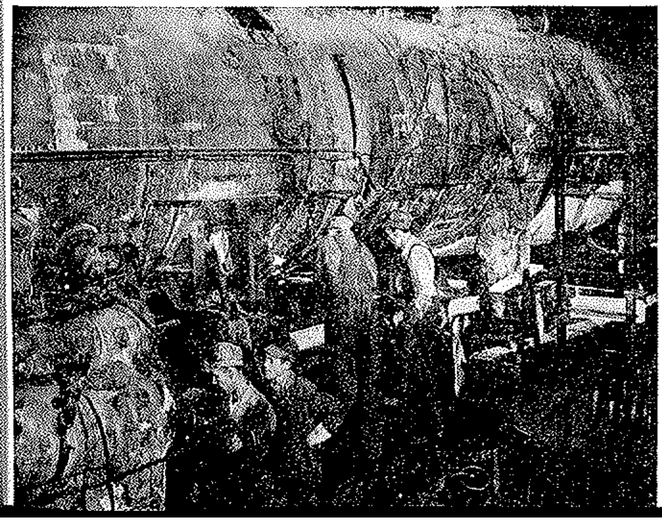
to the superheater header. Here it is distributed to small pipes or superheater units that extend into the flues or fire tubes and returns to the forward pa t of the heater to he delivered to the steam chests or valve chambers. The pressure of the steam on the piston head produces a movement of the piston in the cylinder and the motion is transferred to the driving wheels through the crosshead main rod and side rods.

It is evident that the boiler's efficiency is of first importance and that assistant general boiler inspectors be aware of the condition of all steam boilers and pressure tanks on their respective territories. They in turn examine local boiler inspectors as to the latter's ability and proficiency in inspecting and testing steam boilers, shop pressure tanks and reservoirs, locomotive oil and water tanks, also in testing and inspecting staybolts, knowing that tests and inspections conducted by those shop forces are in strict accordance with Federal laws and Santa Fe rules.

The assistant general boiler inspectors must see that all inspection rules relating to power plants and other stationary boilers and pressure tanks are complied with; that boilers are properly washed and cleaned; that brick work and other settings are in good condition; that steel smokestack bases, breeching and manholes, steam or other leaks or other defects which are included in inspection reports are put in good condition. They insure that steel stack bases, boiler fronts and breeching present a clean appearance and that boiler rooms are kept in proper shape.

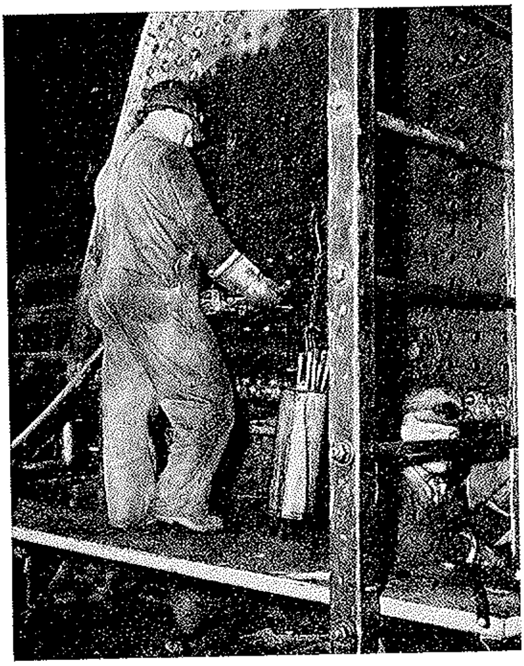
Gas and electric welding processes and appliances are checked, as well as the use of the cutting torch. If procedures are not in line with Welding Folio instructions, the assistant general boiler inspectors suggest proper methods explaining whether the fault lies with the operator, welding material, machine or appliances. They consult with all boiler foremen and boiler inspectors in shops and roundhouses in regard to

Workmen rebuilding 2900-class steam locomotive.



Workmen in combustion chamber and firebox section of steam locomotive.

condition of power and boiler work which will probably be required when locomotives are shopped so that reliable advance information may be furnished the shops as an aid to expeditious and proper handling. When they determine that a locomotive requires a new firebox, they fill out



Close-up of workman drilling holes for staybolts.

staybolt diagrams showing all the defects and a descriptive letter giving details of the box, number of years in service, mileage made by the old firebox and such other information as will provide accurate description of the condition of the firebox and boiler.

Hot water boiler washing plants, designed to utilize the heat from boilers that are blown out (which heat would otherwise be wasted) have been installed at many Santa Fe points to heat water used in washing and filling boilers. Boilers are filled with hot water so that extreme stresses can be avoided. Boilers being washed are examined to determine that scale is properly removed from the sheets and bolts. If scale is accumulating and not being removed by the washing process it is evident that the water treatment is inadequate and such condition is reported for correction. Many waters are subject to frequent and rapid changes in hardness, and the water treatment division of the test department must be promptly notified of such conditions. There are stated instructions in regard to cooling and washing boilers where hot water is not available. It must also be determined that necessary boiler and boiler washing and cleaning tools are provided and are in good condition and properly cared for; also that all machine tools, such as flue machines of all kinds for cutting out, cleaning, piecing and swedging, are modern and efficient.

All spark arresting devices, including ash pan openings, front end nettings and plates, through which sparks may fall and which must be maintained spark proof, are noted. Threaded staybolts are inspected for size and pitch of thread and for fit; flues for weight and pitting, condition of and number of welds, swedging at fit in sheet and copper flue ferrules and proper setting of the flues; hollow staybolts for detector holes drilled central, also for depth and size or stopped up condition; fitting of patches and sheets, alignment of rivet holes and full size rivet and staybolt heads and for correct driving. Steel car work at Santa Fe car shops is inspected to determine that laying out, punching, drilling, fitting and preparing for riveting or welding is done according to approved methods, to insure good tight seams and to reduce shearing strains on rivets.

The general boiler inspector and his assistants are responsible for the correct rendition of reports covering boilers, tanks and pressure reservoirs on the Santa Fe; also that thorough inspections are made when due in accordance with U. S. Government and Santa Fe requirements. The mileage of flues, and fireboxes, between settings and renewals or repairs, reflects the efficiency of boiler performance and, in addition, the manner in which supervision of such facilities is being conducted.

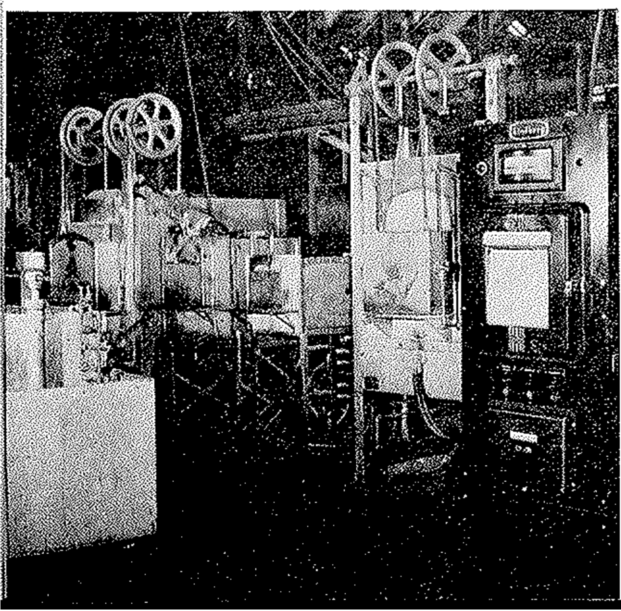
Supervisor of Tools

THE Santa Fe's supervisor of tools, E. J. Kelly, Topeka, assisted by draftsmen, is charged with the supervision and standardization of various shop tools, jigs, and devices used in the repair of Santa Fe locomotives and cars. The supervisor of tools furnishes standard specifications, following up the fabrication process whether tools are made by the Santa Fe or by manufacturers. The department was founded in 1907. Prior to that time the handling of tools on the Santa Fe was not centralized.

Drawings for reamers, cutters, reseating tools, drop pit jacks, driving box presses and miscellaneous portable tools fabricated by the Santa Fe at Topeka shops, are prepared by the supervisor of tools. When these tools are completed they are delivered to the store department as stock items. It has been found economical to carry a stock of tools in the store department. The latter issues the tools upon requisitions approved by master mechanics, mechanical superintendents and the supervisor of tools. The latter keeps the store department informed regarding shop tool standards and smaller machinery and such other tools and machinery as may he shown in the various folios maintained by the supervisor of tools. That enables the store department and others to keep abreast of Santa Fe tool standards.

The supervisor of tools issues the Santa

Heat treating furnaces in tool room of Topeka shops.



E. J. Kelly, supervisor of tools, with headquarters in Topeka, Kan.

Fe's rules and instructions for belt repairmen. The department also maintains the following Santa Fe folios:

Mechanical Department Standards. Standards governing machine-tool equipment, shop facilities and methods with rules and regulations in regard thereto.

Standard Tool Steel Folio. High speed, alloy, and carbon tool steel for use in manufacturing various tools and machine parts.

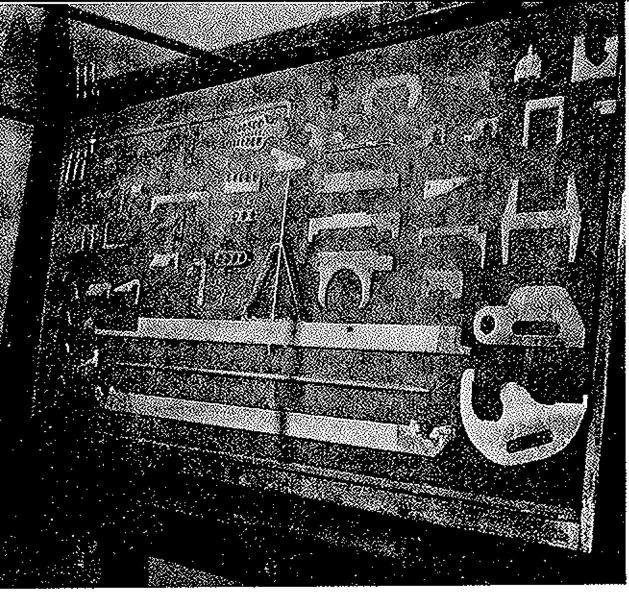
Abrasive Polio. Abrasive wheels in use in mechanical department, shops, roundhouses, as well as the timber treating plants and the Santa Fe's rail mill at Newton; also mounted wheels and points, grinding compounds, abrasive cloths and papers, as well as abrasive sticks or honing stone.

Packing Leather Folio. Packing leathers for use in shops and roundhouses also in maintenance of way work.

Track Tool Folio Repair Limits. Various track tools that are repaired by the Santa Fe mechanical departments. Gives renair limit for the various items shown, and proper method of repair.

Folio of Repair and Maintenance Tools for Diesel Locomotives.

In addition to acquainting all concerned with established Santa Fe standards, the



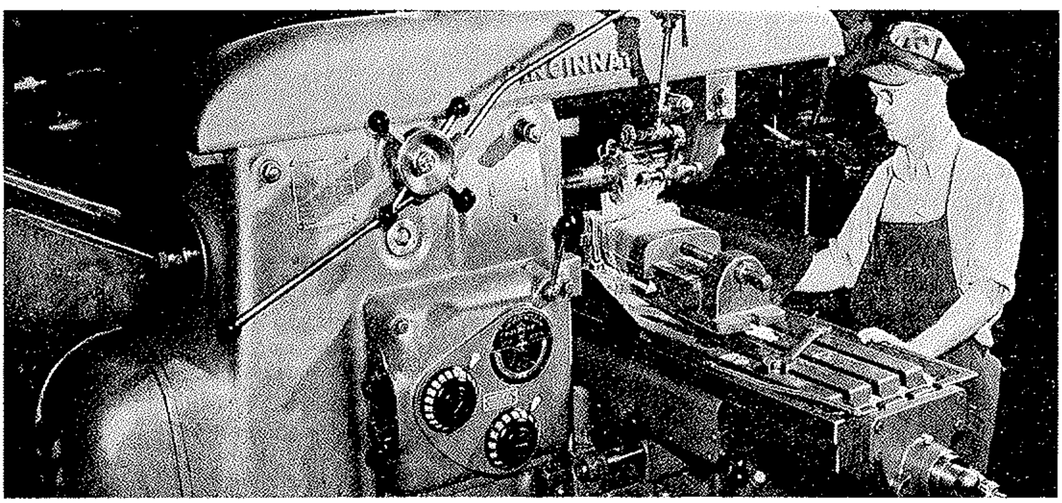
Display of gauges used by Santa Fe mechan-**ical** department.

folios simplify procedures in ordering tools. A tool and machinery pattern record book, containing various pattern numbers, the description and location of tool patterns, also the drawing number of the pattern and the weight of the casting made from the various patterns, is maintained by the supervisor of tools. The book contains a total of 4,565 patterns of various Santa Fe shop tools and machinery. At all Santa Fe shops, there is a mechanical department stock book, which is an inventory of the tools used in a particular shop. The books are made up in printed form and are forwarded to the supervisor of tools each six months for checking. The books serve many purposes, being of particular importance in case of fire. In relation to the latter, the supervisor of tools receives a monthly report from all shops and roundhouses that all cupboards and lockers have been inspected in relation to the presence of fire hazards and surplus tools found therein are returned to the tool room. Tools are issued to Santa Fe shopmen on tool checks.

Reduction in the number of tools required in mechanical procedures, with resultant economies in labor and costs, has been a prime objective of the department.

The supervisor of tools has general supervision of Santa Fe track motor cars used by section forces, inspectors, engineering parties and others, maintaining a complete record of such cars totaling some 2,400. Motor car maintainers are located at various points throughout the system and it is their duty to repair the cars, sending daily reports to the supervisor of tools. The Santa Fe first standardized its track motor cars in 1823. At that time there were 1,200 such cars in service, representing thirty-eight different classes or models. The classes since have been reduced to six. Considerable economies were effected by that standardization as well as increased efficiency in operation of the cars.

Complete sets of drawings covering details and specifications of Santa Fe push cars are maintained by the supervisor of tools. The drawings are used for shop use in repairs to cars and for store and purchasing department use in the purchase of new push cars. The Santa Fe's push cars likewise have been standardized and considerable economies effected. All cars are interchangeable and it is now possible to carry a reasonable stock of repair parts. There are approximately 1,800 such cars in Santa Fe service.



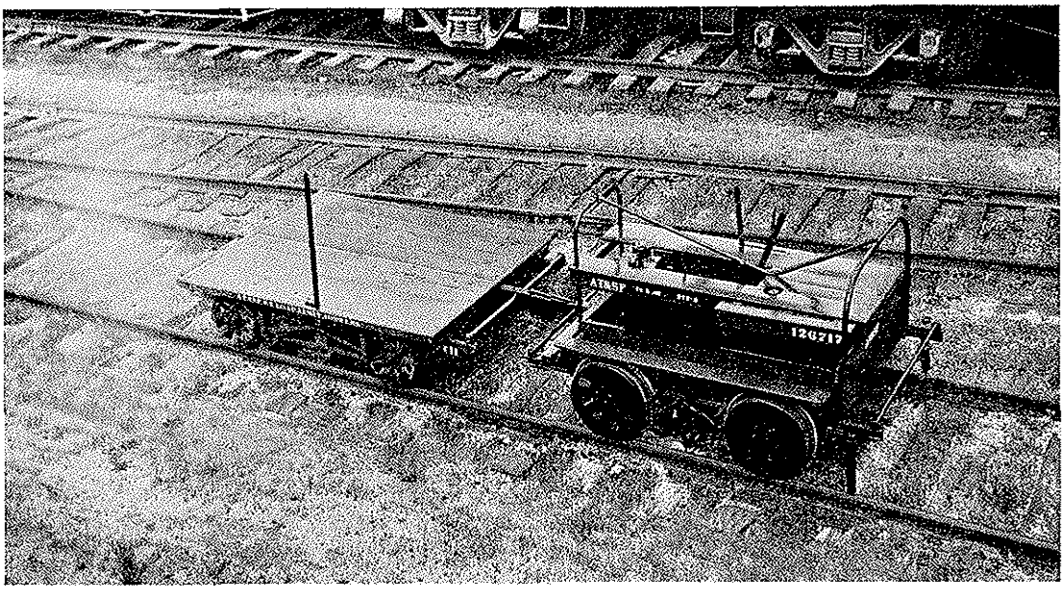
New milling machine in tool **roam of** Topeka **shops.**

The supervisor of tools supervises the maintenance of all baggage trucks and standards in relation thereto. There are some 1,800 baggage trucks in use at Santa Fe stations. All have wheels of the same size, equipped with roller bearings, permitting an ease of operation not possible prior to standardization. Detailed drawings of all parts of station baggage trucks are maintained for use in repairs and in the purchase of new baggage trucks.

All Santa Fe shops and roundhouses having portable air or electric driven grinders furnish the supervisor of tools a monthly report showing the speed of the various grinders. That enables continuous check on the safe and efficient operation of such grinders. The supervisor of tools also is furnished a monthly report on portable jacks in use, showing the condition of the jacks and other pertinent information. Keeping a jack well oiled and conditioned is an important safety measure. The Santa Fe's mechanical department has some 7,200 manually operated jacks in addition to air operated power jacks. The department also must insure that one gasoline-operated turntable motor and a transmission are on hand at all times at Albuquerque shops to protect the various turntables which require that equipment and that proper repair parts are furnished those turntable motors and transmissions.

The supervisor of tools makes frequent inspection trips over the line, checking tool matters, motor and push cars, baggage trucks and other facilities under his supervision. Tool cupboards are checked for neatness and the presence of fire hazards. Attention also is given to ladders and trestles to determine if they are maintained in a safe, efficient manner, and that all other instructions issued by the department or contained in the folios under its direction are properly observed.

Certain necessary articles, "small supplies," are carried by each locomotive. Those articles include small tools, oilers and oil cans, and important signal equipment, lanterns, flags, fusees and torpedoes. There are rules and regulations in regard to the necessary presence on the locomotive of standard quantities of most of those items, particularly signal equipment, depending on the class of service the locomotive performs —passenger, freight, switching and other operations. E. J. Kelly, supervisor of tools, supervises small supplies for locomotives throughout the Santa Fe's lines. The supervisor of tools determines that shops and terminals have ample supplies of those articles on hand and that proper quantities are placed on each locomotive. He also instructs Santa Fe people engaged in those duties so that there will be no failures or misunderstandings.



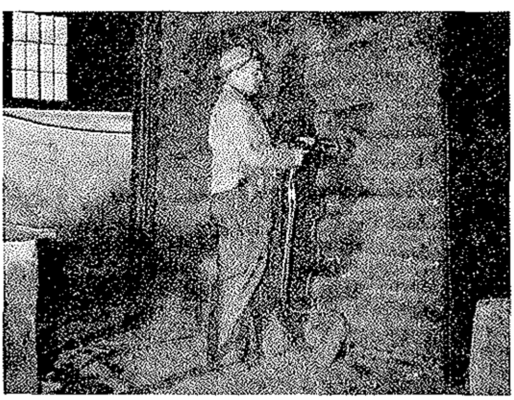
The supervisor of tools has general supervision of Santa Fe track motor cars used by section forces, inspectors, engineering parties and others. Here is a track motor car with push car for transporting workmen.

Supervisor *of* Welding

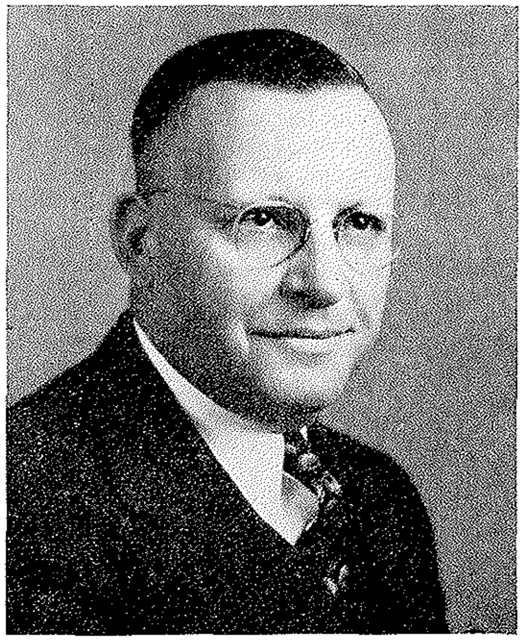
THE supervisor of welding, H. A. Patterson, Topeka, is charged with developing and establishing structurally safe and economically sound fusion and resistance welding practices in relation to repairs and manufacture of Santa Fe locomotives, cars, shop machinery and other Santa Fe rolling and fioating equipment. That responsihility includes the proper technique for weld metal application and related operations including joint preparation, choice of processes, heat treating after welding, filler material specifications, mechanical working of weld ingots, fiame hardening and stress relieving.

The supervisor of welding is the author of welding instructions and procedures as carried in the Santa Fe's important Welding Folio of approved welding standards. Those procedures are developed in collaboration with the engineer of tests, mechanical engineer, general boiler inspector, engineer of car construction and other mechanical department officers; also with Hospital Association medical officers. The Santa Fe early gave attention to welding processes, introducing the practices of welding patches in fireboxes, welding flues by both the oxy-acetylene fiame and electric arc methods, and oxy-acetylene cutting. Improved methods and safety practices in welding have long been an important concern of the Santa Fe's mechanical department.

The supervisor of welding instructs Santa Fe welding operators and supervisors on welding techniques and practices, checks



Welding studs on boxcar end



H. A. Patterson, supervisor of welding, with headquarters in Topeka, Kan.

condition and performance of all welding equipment, advises store department of anticipated welding material needs, and investigates the ability of and welding methods employed by those firms whom the Santa Fe contracts to perform specified work. Fusion welding practices, at this time, are in a fluid stale of development and the supervisor of welding must closely follow each development so that Santa Fe standard practices may be the safest and most efficient developed. Welding processes now used include the following:

Fusion welding. A group of processes in which metals are welded together by bringing them to the molten state at the surface, to be joined with or without the addition of filler metal and without the application of mechanical pressure or blows.

Arc welding. A non-pressure (fusion) welding process wherein the welding heat is obtained from an arc either between the base metal or weld metal and an electrode, or between two electrodes.

Gas welding. A non-pressure (fusion) welding process wherein the welding heat is obtained from a gas flame.

Resistance welding. A pressure welding process wherein the heat is obtained from the resistance of the flow of an electric current.

Flash butt welding. A resistance butt welding process wherein the necessary heat is derived from an arc or series of arcs established between the parts being welded prior to the application of the weld consummating pressure, which is applied when the heat thus obtained has produced proper welding conditions.

Thermit welding. A fusion welding process based on a chemical reaction between iron oxide and aluminum that produces highly super-heated iron and aluminum oxide slag.

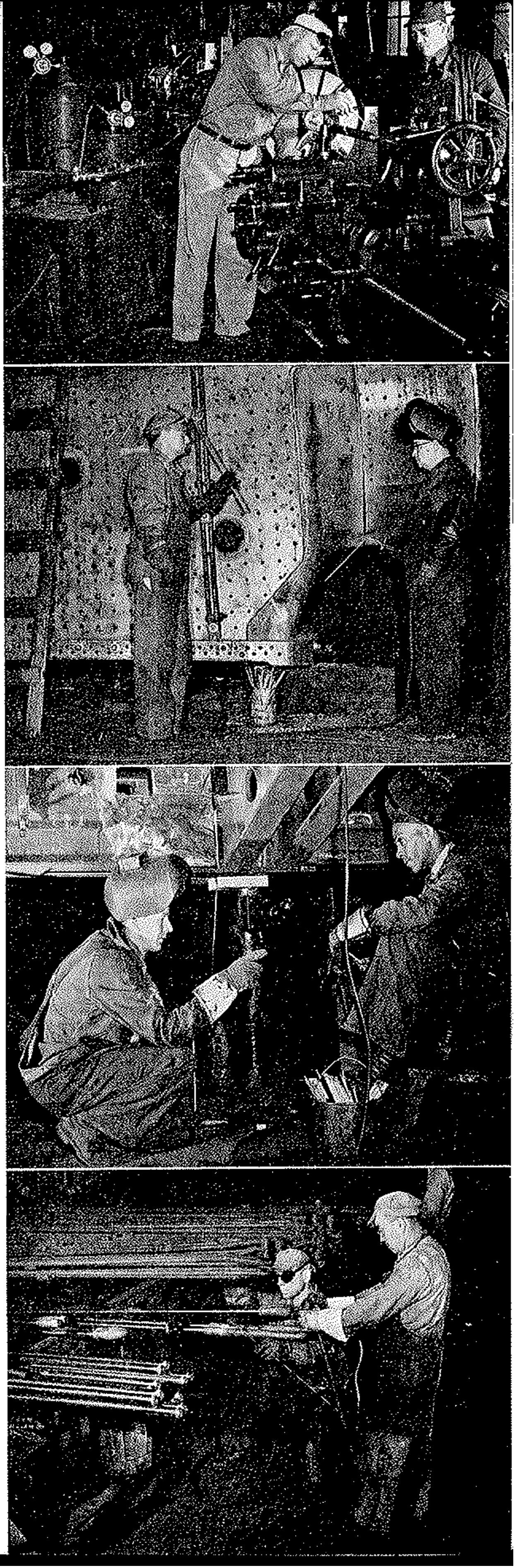
Spot welding. A resistance welding process wherein the fusion is confined to a relatively small portion of the area of the lapped parts to be joined by the shape or contour of one or both welding electrodes.

Shot welding. A spot welding process where the welding time, applied pressure, and electric current are calculated and controlled.

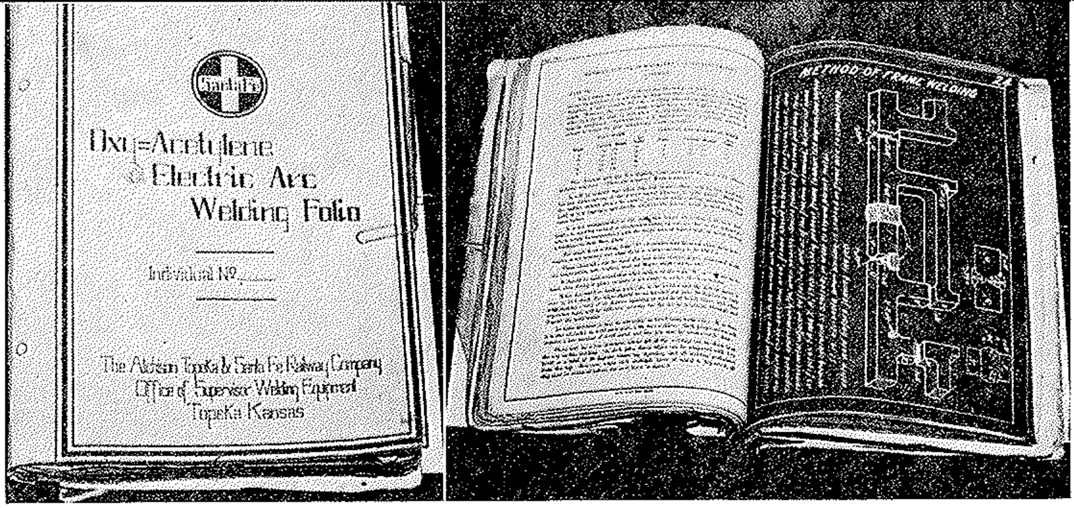
Oxy-acetylene cutting. A process of severing ferrous metals by means of the chemical action of oxygen on elements of base metal at elevated temperatures.

The Santa Fe's first oxy-acetylene welding and cutting operations were attempted in 1907. An experimental plant was built in which was generated oxygen and acetylene. The first welding operation of importance was the welding of tubes in a smokebox superheater. In 1909, the Santa Fe began the use of torches for cutting out defective parts of fire box and welding in new patches. In 1910, a new and larger gas generating plant was built at Topeka and cutting and welding operations were greatly increased. Similar plants were installed at that time at San Bernardino, Albuquerque, LaJunta and Cleburne. At Shopton, an acetylene generator only was installed and a manifold for distributing oxygen received in high pressure cylinders. The portable cylinder and manifold method of feeding gas-at reduced pressure into the shop pipe lines was set up at other shops.

The Santa Fe's first electric welding operations were carried on in the spring of 1913. An "Ideal" engine and directly connected DC generator were used. wires being run to several locations on the erecting floor. The generator was designed to deliver current at 125 volts, the desired lower voltage being obtained by separately exciting the fields of the generator with current from the power house, the excitation being



Modern welding practices in Santa Fe shops. Top—Welder and motion gang supervisor metalizing air pump piston rod. Second—Two men starting to weld on a locomotive boiler. Third—Coach shop welders discussing welding implement. Bottom—Machinist welder and helper with superheater welding unit.



Improved methods and safety practices in welding long have been an important concern of the Santa Fe's mechanical department: Above, left, is a close-up of Oxy-Acetylene and Electric Arc Welding Folio. At right, the welding folio is shown opened to "Method of Frame Welding."

controlled by passing the current through banks of incandescent lamps. Flues were welded to the back flue sheets of two locomotives of the 1480 class which had been shopped for heavy repairs. Instead of removing the flues, the beads of the flues and the bridges between them were sandblasted and the old beads were seal welded to the flue sheet. Both of those engines ran for seven months before it became necessary to lake out the flues. The experiment proved that there was merit in the practice of seal welding the beads of locomotive flues and the practice became standard on the Santa Fe. Arrangements later were made to purchase and install electric welding machines built to snit the work they were to perform.

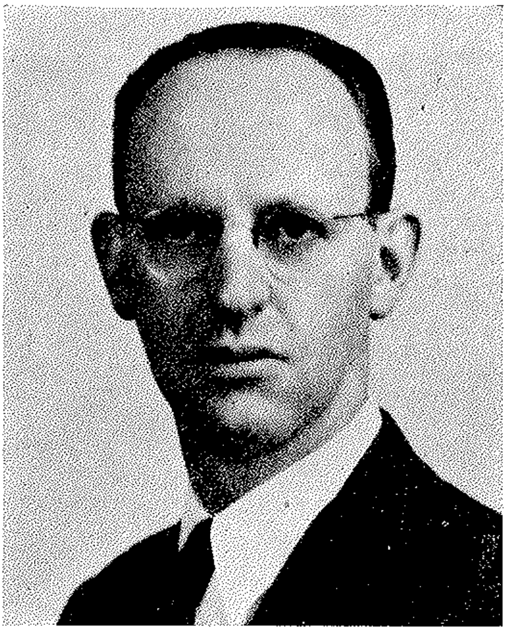
Truly remarkable progress has been made in electric welding since that time as well as in all other welding operations. The use of oxy-acetylene welding and cutting as well as electric welding in the fabrication of railway equipment and in the task of reclamation has enjoyed a steady and ever-broadening development. Carefully trained welders working under proper supervision have always been essential requirements in welding operations.

Supervisor of Mechanical Training

THE supervisor of mechanical training, W. D. Major, and his assistant, F. J. Repman, both of Topeka, have charge of the training of supervisors and apprentices.

There are at the present time approximately 900 apprentices of the various crafts in service. Young men are given practical experience in the various shop crafts. They work under a designated foreman, receiving at the same time detailed instructions from a shop apprentice instructor who devotes his entire time to the teaching of apprentices. Apprentices must attend evening school twice weekly, forty minutes' school time being required for each day's work in the shop. A school instructor teaches them mechanical drawing, sketching, shop arithmetic, elements of mechanics and other theoretical and technical training procedures to supplement the actual experience gained under the shop apprentice instructor. A detailed record is maintained of the progress of each apprentice. They are indentured in a craft in which they seem adept—carman, machinist, boilermaker, sheet metal worker, blacksmith and electrician, among others. Their period of apprenticeship is for three or four years, during which time they must meet attendance and scholastic requirements. An apprentice board, under the chairmanship of the local head mechanical officer, meets regularly to discuss the progress of each apprentice.

School rooms are maintained at 29 locations over the system under the supervision



W. D. Major, supervisor of mechanical training, with headquarters in Topeka, Kan.

of twenty apprentice instructors. Some of the smaller points are covered by traveling apprentice instructors, who usually spend two days a week at each point to take care of school-room work and to check the progress of the apprentices in their shop work. The largest school rooms are located at Topeka, San Bernardino and Albuquerque.

The Santa Fe's apprentice system began unofficially in Shopton, Iowa, in 1901, when John Purcell, its founder, supplied on his own initiative this long-felt need. In 1907, Vice-President J. W. Kendrick instructed Mr. Purcell to establish the system as an official Santa Fe practice. By 1924, the enrollment had reached 1,900, the supply of graduates exceeding the Santa Fe's needs. During the 1920s there were forty apprentice schools on the Santa Fe's lines. Other railways, staffed by Santa Fe's trained men, have profited from the Santa Fe apprentice system. Many Santa Fe mechanical supervisors are graduates of the school. More than 8,000 men, all qualified shopmen in their particular fields, have graduated from the school. Graduates really acquire two trades, as all are qualified draftsmen.

Courses in modern industrial training techniques have been set up for the benefit of supervisors. The courses so far held consist of two steps. The first is known as *job instruction.* This course helps the supervisor to improve the quality of production, stresses safety, and enables him to be a better leader of men. The second step is known as *job methods.* This enables-the supervisor to obtain maximum utilization of machines and man power, and also deals with the problem of handling men. Each of these two courses consists of five two-hour sessions. The job methods course follows about six months after the job instruction course. The courses are supplemented hy the showing of sound films dealing with problems in supervision. Mr. Repman has been especially trained to conduct these supervisory training courses.

Santa Fe apprentice school at Topeka, with instructor and students. The Santa Fe inaugurated the apprentice system in the early 19C0s, and since then other railways, staffed by Santa Fe's trained men, have profited from it. School rooms are maintained at 29 locations over the system, the largest being located at Topeka, San Bernardino and Albuquerque.

Mechanical Valuation Engineer

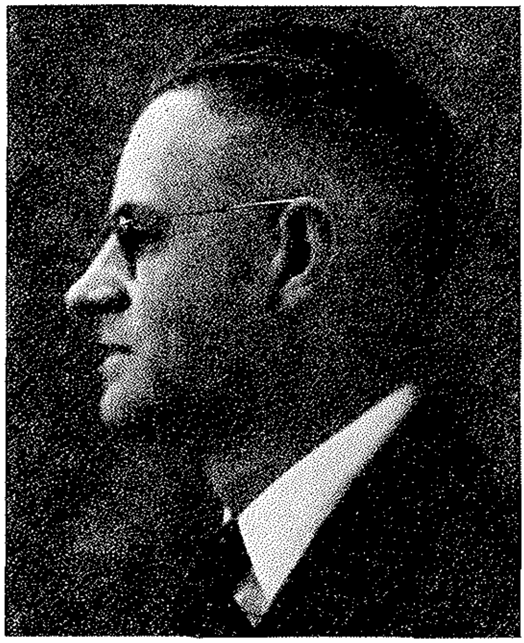
The office of mechanical valuation engineer of the Santa Fe system lines, under the direction of the assistant to vice-president in charge of operation, was established at Topeka in 1916 to facilitate the task of determining the value of certain Santa Fe properties included within the requirements of Section 19a of the Interstate Commerce Act of March 1, 1913, which ordered:

That the Commission shall, as hereinafter provided, investigate, ascertain, and report, the value of all property owned or used by every common carrier subject to the provisions of this part, except any street, suburban, or interurban electric railway which is not operated as a part of a general steam railroad system of transportation.

The Santa Fe properties included within the scope of the mechanical valuation engineer were and are:

Gas production plants..
Power transmission system.
Power distribution system.
Power line poles and fixtures.
Shop machinery.
Power plant machinery.
Power substation apparatus.
Steam locomotives.
Other locomotives (Diesel, gas-electric).
Freight train cars.
Passenger train cars.
Floating equipment.
Work equipment.
Miscellaneous equipment (automobiles, trucks, horses, mules).

The task of determining the value of those Santa Fe properties was handled by the mechanical section of the Bureau of Valuation, Interstate Commerce Commission, and was effected by the Commission's mechanical engineers assisted by members of the Santa Fe's mechanical valuation department. The latter were designated as "pilots". The mechanical valuation task was divided into three groups of parties: Motive power, car equipment, and machinery. The date of the inventory was as of June 30, 1916. All points on the Santa Fe system were inspected. The Santa Fe representatives acting as pilots with each of those parties were familiar with the Santa Fe's mechanical properties. They observed in detail the methods used and the records made by the Interstate Commerce Commission field parties; also assisted in identifying and measuring the property concerned, and ascertaining facts bearing on quantities and conditions of properties. Upon completion of the field inventories, Valuation Order No. 8 was prepared and filed with the Interstate Commerce Commission. That report covered the recording and reporting of Register of Equipment and original cost to date (June 30, 1916) as prescribed by the Interstate Commerce Commission, Bureau of Valuation. The I.C.C. in turn Drepared a report commonly known as the Engineering Report.



W. S. Lammers, mechanical valuation engineer, with headquarters in Topeka, Kan.

Section 19a of the Interstate Commerce Act also provided the following:

Upon completion of the original valuations herein nrovided far, the Commission shall thereafter keep itself informed of all new construction, extensions, improvements, retirements, or other changes in the condition, quantity, use, and classification of the property of all common carriers as to which original valuations have been made, and of the cost of all additions and betterments thereto and of all changes in the investment therein, and may keep itself informed of current changes in costs and values of railroad properties, in order that it may have available **at** all times the information deemed by it to he necessary to enable it to revise and correct its previous inventories, classifications, and values of the properties; and when deemed necessary may revise, correct, and supplement any of its inventories and valuations.

And further:

To enable the Commission to carry out the provisions of the preceding paragraph, every common carrier subject to the provisions of this part shall make such reports and furnish such information as the Commission may require.

In order that uniformity would be attained in fulfilling those requirements, and in order that the Interstate Commerce Commission could be kept informed of all extensions and improvements or other changes in conditions or values of Santa Fe properties, it has been necessary since the date of inventory, June **30,** 1916, annually to prepare and furnish the Commission, in prescribed form, that information as covered by the Commission's Valuation Order No. 3 and subsequent revisions.

To effect that, the mechanical valuation engineer's office mas continued and is today the responsibility of W. S. Lammers, mechanical valuation engineer, Topeka, assisted by a force of valuation assistants and equipment clerks. In general, the work is of an accounting, engineering and statistical nature pertaining to the Santa Fe's machinery and rolling equipment. Only about fifteen per cent of the work is directly for valuation purposes in compliance with the Interstate Commerce Commission Act. The more important phases of the work include the following:

Tax and insurance schedules and statements.

Completion reports furnished auditor for new machinery purchased and old machinery retired or transferred; new equipment acquired and old equipment retired, including additions and betterments applied to existing equipment.

Valuation reporting covering all changes in shop and power plant machinery and rolling stock.

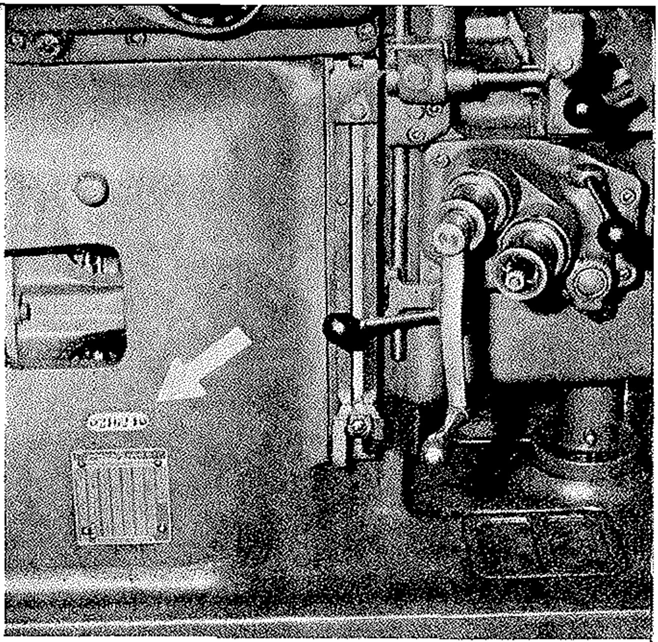
Depreciated values, appraised values, original cost, reproduction cost, and salvage values for machinery and equipment as requested.

Maintenance of "live" list and historical record of all machinery and rolling stock.

Miscellaneous statistical statements compiled and furnished upon request.

Revision and distribution annually to all mechanical department officials, shop machinery record.

Development of cost studies in shops of all



Representatives of the mechanical valuation engineer apply number plates to all, machines on the Santa Fe system lines. Here is a close-up of numbering Plate on the new type milling machine in the Topeka shops.

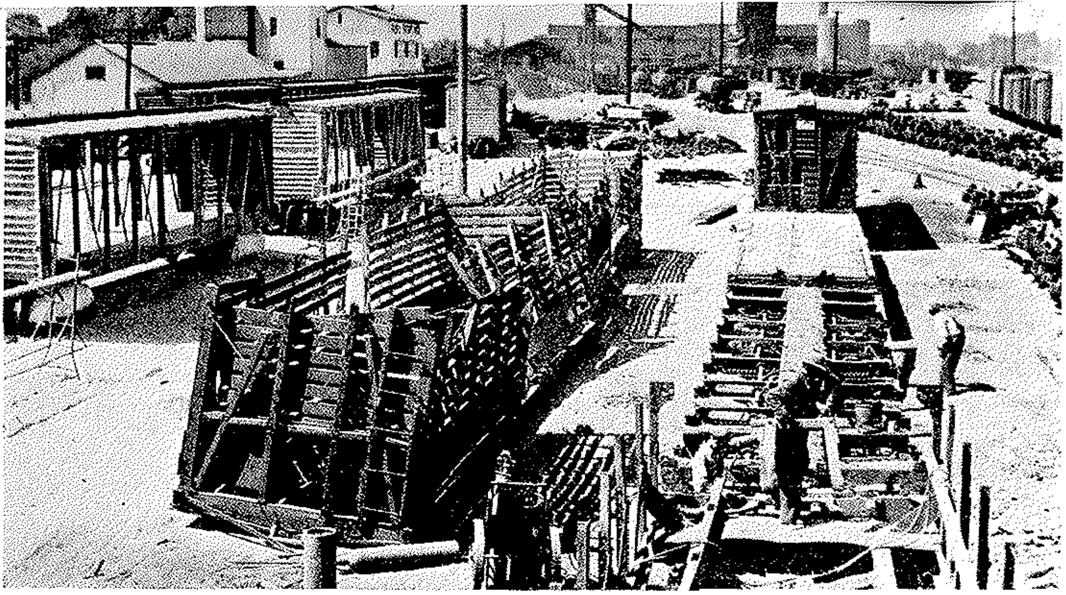
additions and betterments applied to rolling stock.

To perpetuate basic valuation and historical data, the material compiled by the department is recorded on especially designed forms and maintained in systematic order in a fireproof vault.

When the field inspection was first made, difficulty was experienced in identifying the various machines used in shops and at other localities throughout the Santa Fe's lines. When the inspection was completed, a numbering system was adopted. Representatives of the mechanical valuation engineer applied number plates to all machines on the Santa Fe system lines—a nine months' task. A number plate since has been applied to each new machine installed.

A special card system has been adopted for recording all equipment retired, equipment retired but not dismantled, equipment renumbered, additions and betterments applied to equipment, and new equipment units purchased and equipment converted from one class to another.

The mechanical valuation engineer also serves on the subcommittee of the Joint Equipment Committee, the latter composed of railway representatives appointed by the Association of American Railroads, and representatives of the Interstate Commerce Commission's Bureau of Valuation. That committee meets in Washington each year



Dismantling an old stock car that can no longer be used. Bolts are cut with torches and the wooden part is rolled to the side where it is torn down and later burned. All metal that is good is saved and used to rebuild cars that can be repaired. Mechanical valuation engineer's record shows the car being dismantled is No. 55701 and was built in 1907 by tho American Car and Foundry Company at a cost of $1,542.73.

lo analyze new equipment purchased during the previous year by all railways in the United States to determine the cost of railway equipment and machinery. The Committee's report, after approval, is published and distributed by the Association of American Railroads' finance, accounting, taxation and valuation department.

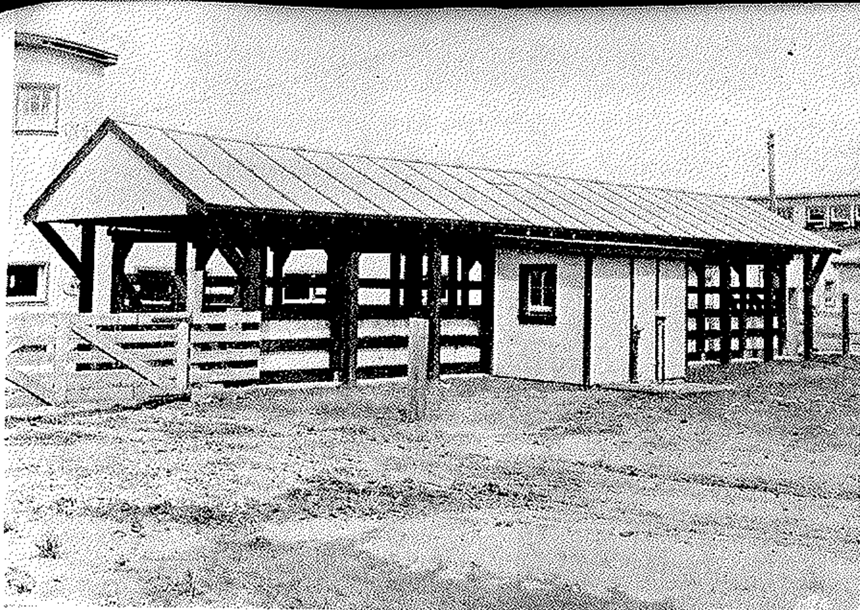
Chief Scale Inspector

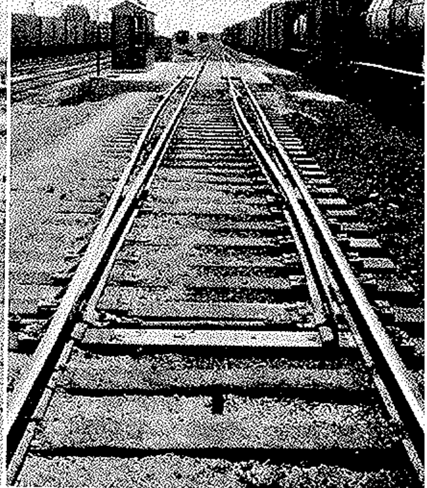
THE chief scale inspector, William Horacek, Topeka, heads the Santa Fe's scale test department the functions of which are to maintain to a high degree of accuracy the 2,500 scales owned by the Santa Fe. Those scales are of various types including track, truck, stock, coal chute, automatic dial warehouse, baggage and freight and grain weighing hopper scales, utilized for the assessment of charges for freight shipped in carlots and less-than-carlots and also to a lesser degree in the purchase of commodities for use by the Santa Fe.

The capacity of the various types of Santa Fe scales ranges from the small postal scale in use in many Santa Fe offices to the large 150-ton capacity track scale used exclusively for weighing carload freight. Included are twenty-four individual locomotive scales located at Topeka shops on rvhich are weighed all the various types of steam locomotives as well as Diesel-electric powered passenger, freight and switch locomotives.

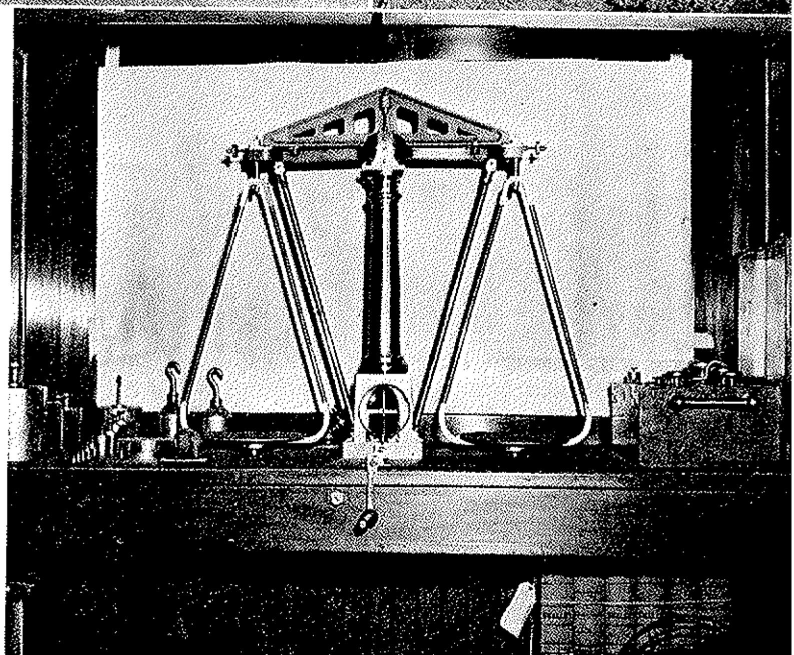
A master track scale especially designed and built for the express purpose of calibrating the Santa Fe's three 80,000-pound test weight cars is located at the Santa Fe's main scale shop at Topeka; also a master even arm balance. The latter has a capacity of 50 pounds in each pan and is sensi-

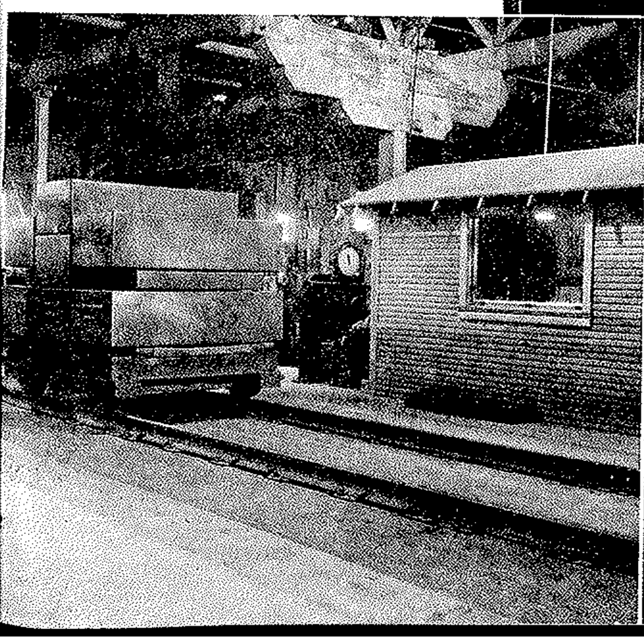
William Horacek, chief scale inspector, with headquarters in Topeka, Kan.

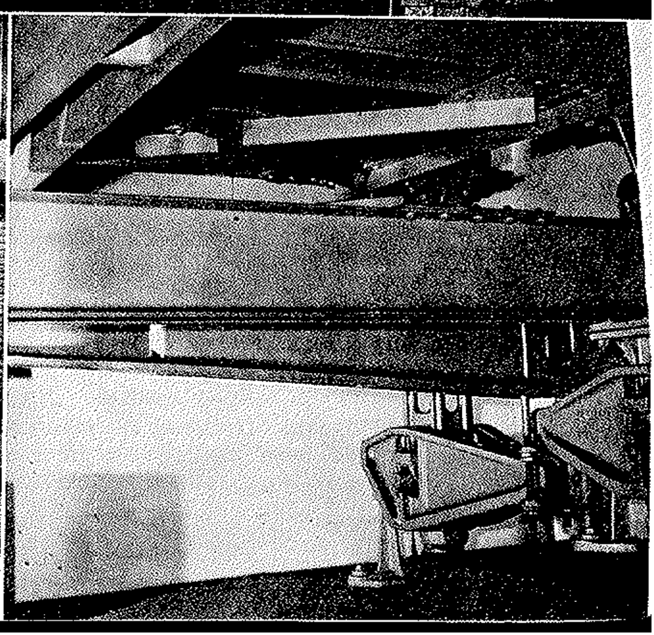


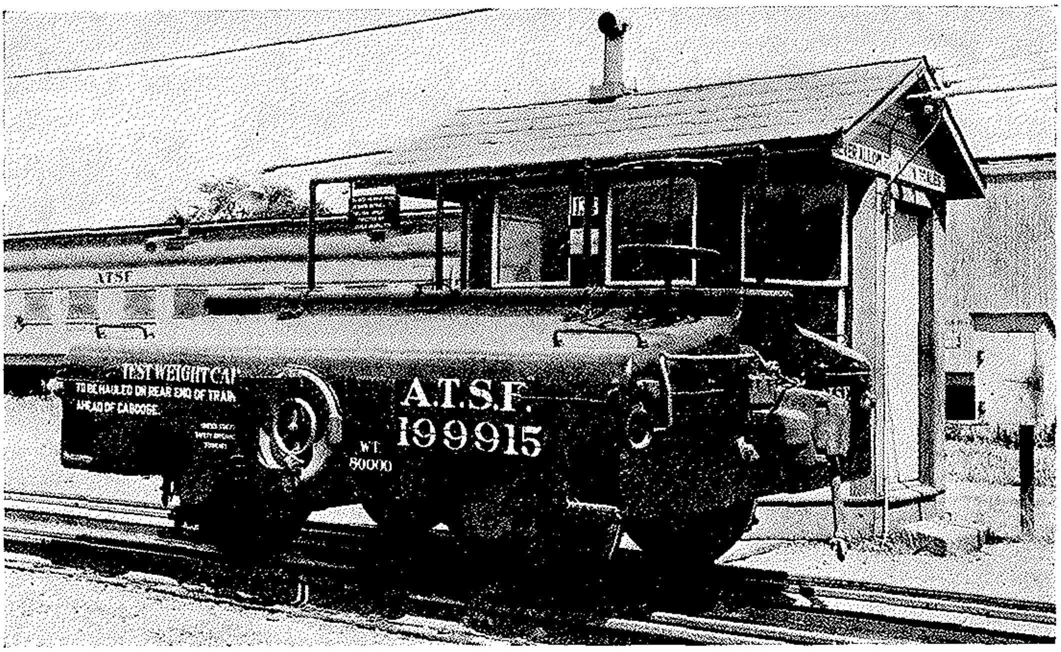


Santa Fe weighing facilities provide good weights. Upper left—Stock scales at Emporia, Kan., and Dodge City, 40,000 pounds capacity, platform 13 by 51 feet, are the largest scales of this type known used for weighing double-deck carload of sheep on hoof. Upper right—Standard 150-ton, 50-foot track scale for weighing carload freight. Center—Master even-arm balance for calibrating master weights. Lower left—Master track scale at Topeka shops being calibrated with U. S. Bureau of Standards testing equipment totaling 100,000 pounds of test weights. Lower right—Pit view of master track scale.









One of three track scale test weight cars used for calibrating track scales. Weight 80,000 pounds, wheel base 7 feet.

tive to 1-70,000th part of a pound. With a master set of bronze gold-plated weights ranging in size from 1-10th of a grain to fifty pounds, it is employed in the standardization of the well known 50-pound test weight which is used for calibration of the different types of scales except the track scales. Those two master weighing units are calibrated at yearly intervals by the National Bureau of Standards for the fundamental purpose of maintaining them in as near a perfect state of weighing accuracy as it is possible to obtain.

The Santa Fe's main scale shop at Topeka through which all Santa Fe scales at one time or another pass for repairs, is one of the most modern and complete shops of its kind in the United States. The chief scale inspector has a staff of seven scale inspectors who inspect Santa Fe weighing facilities within specified districts throughout the Santa Fe's lines. Those inspectors are located at Topeka, Shopton, Newton, Albuquerque, Amarillo, Cleburne, and San Bernardino. They install, repair and test scales, maintaining the scale equipment as near as possible to sixteen ounces to the pound. Confidence in the accuracy of the scales is an important asset to Santa Fe patrons and to the railway itself.

Since 1914, the National Bureau of Standards has been testing the master scales used by railways for sealing the test cars which are moved about the lines of all railways for the purpose of testing track scales used in weighing carload freight. The Bureau likewise tests track scales of individual railways as the Bureau's test crew moves about the country from one master scale to another. On an average, fifteen Santa Fe track scales, located at different points on the system lines, are checked annually by the National Bureau of Standards. The Bureau uses a tolerance of 0.20 per cent, equivalent to two hundred pounds, plus or minus, on 100,000 pounds. The annual report of tests given railway and industry track scales by the Bureau discloses that the Santa Fe's track scales, year after year, are maintained well within the prescribed tolerance. That means that Santa Fe weighing facilities provide good weights.

Santa Fe patrons benefit from that high average and may place confidence in the track scale weights of carload commodities they forward or receive, which have been secured by a Santa Fe sworn weighmaster. Some Santa Fe patrons have their own track scales, located adjacent to Santa Fe tracks. Those scales are given the benefit of Santa Fe scale test car service.

Track scales are located at all large Santa Fe stations, important junctions, terminals, and at other points where freight carload shipments originate or concentrate.

General Mechanical Inspector

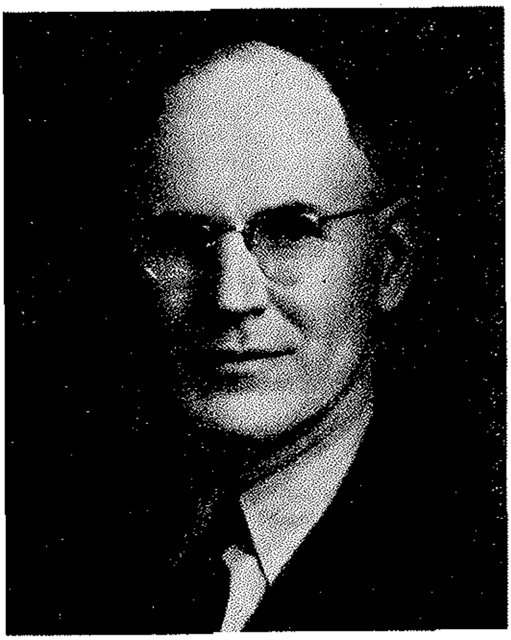
THE Santa Fe's general mechanical inspector, J. L. Fertig, Topeka, is attached to the personal staff of the assistant to vice-president in charge of operation. A specialist in all phases of Santa Fe mechanical practices and procedures, the general mechanical inspector observes all operations relative to locomotives, roundhouse machine shops, blacksmith shops, tool rooms, and shop premises. He also rides locomotives and generally inspects Santa Fe motive power insuring that it is in a safe and suitable condition.

It is a responsibility of the general mechanical inspector to see that proper repairs are made to locomotives, that defects reported are taken care of as they occur, that all Federal rules are observed, that all appliances on locomotives are used, that locomotive inspectors make proper inspection and reports and that all outstanding instructions pertaining to mechanical matters are carried out.

Work equipment is observed to determine that it has been given proper repairs. It is necessary that machine shops machine parts to standard specifications and according to blueprints; that machines be properly maintained; that all parts in blacksmith shops are correctly made to avoid waste of time and material when machining; that no serviceable material is scrapped; that tools are properly kept; and that locomotives are properly supplied befo e leaving terminals and properly serviced at all servicing stations.

The general mechanical inspector discusses conditions found at each point with supervisors and also renders a written report. Engine failures are discussed at each terminal. Effort is made to determine cause of failures to prevent recurrence. Sometimes locomotives give trouble of an unusual nature and they are ridden in order that trouble may he located. The cost of engine handling is observed at each terminal and comparison of methods on a system basis is made so that preferred methods may be adopted at all terminals. Locomotives out of service represent a considerable investment standing idle. When such conditions are found, full facts as to the reason for being out of service, how long out, and when likely to return to service, are developed.

All those features of railway inspection have a direct bearing on service and economy as well as safety and are of basic importance in Santa Fe operations.



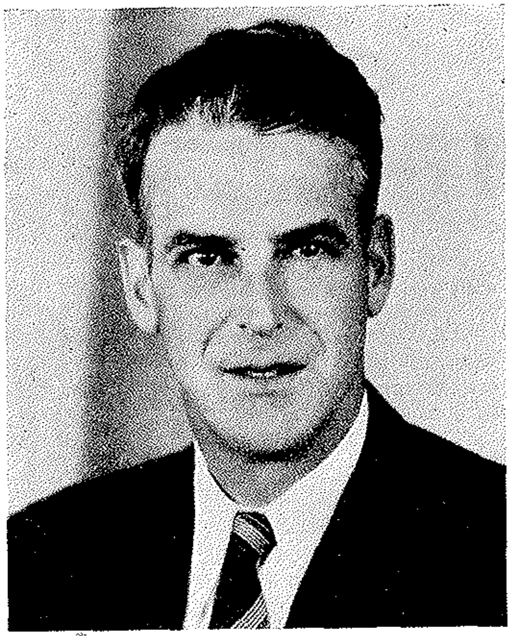
J. L. Fertig, general mechanical inspector, with headquarters in Topeka, Kan.

General Car Inspector

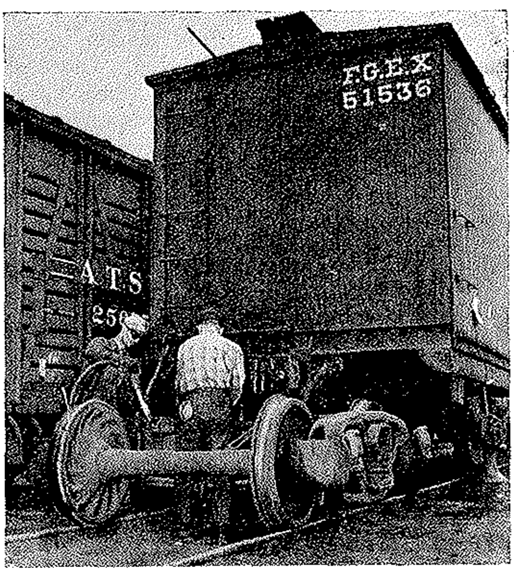
THE general car inspector, G. Nirschl, Topeka, is charged with system-wide observation of repair work done to freight cars at Santa Fe shops. He checks each shop point to see that work is handled properly, that proper tools are available, that work accomplished is commenstirate with number of men employed, that labor is properly balanced and that supervisors are efficient and capable. Damaged Santa Fe cars are appraised to determine whether they are to be repaired or dismantled and obsolete equipment as to whether it is to be maintained or dismantled.

Freight and passenger cars owned by other railways which may be badly damaged on Santa Fe rails are appraised to determine if Santa Fe should repair, if car should be sent to the owner line for repairs, or if Santa Fe should settle on basis of car's depreciated value. That same procedure is given Santa Fe cars badly damaged while on rails of other lines—whether Santa Fe desires cars sent home for repairs or settlement by other line on basis of cars' depreciated value.

The general car inspector's staff includes three traveling car clerks, each assigned to a portion of the system lines, who check all records of repairs made by Santa Fe shops to foreign cars against repair bills to insure that all items of repairs have been properly billed against the owner line, that no items of repair have been omitted, that no items have been included which were not performed, and that all work done to cars and the billing of the charges against the foreign lines complies with Association of American Railroads' code of rules governing the condition of, and repairs to, freight and passenger cars for the interchange of traffic.



G. Nirschl, general car inspector, with headquarters in Topeka, Kan.



Fruit Growers Exchange car being repaired in Santa Fe shops at Argentine, Kan. All repair work done to foreign line cars while they are on Santa Fe rails is made in accordance with A. A. R. rules, in which responsibility for repairs is clearly set forth.

The above mentioned code of rules has been formulated as a guide in the fair and proper adjustment of all questions arising between car owners and railways handling the cars when off owners' rails. Responsibility for repairs is clearly set forth. That covers damage and other unusual causes as well as ordinary wear and tear in fair service, according to safety requirements and standards of the A.A.R. Unfair usage and improper protection of cars are defined and basis for charging all rewairs is clearlv set forth. The rules also cover materials, method and other practices and procedures.

The traveling car clerks check general conditions on Santa Fe repair tracks to see that repairs are being made in compliance with Santa Fe and A.A.R. rules and that proper materials are being used in repairs to foreign cars as required by A.A.R. rules. They also call on private line car owners as well as foreign line railways in regard to the settlement of disputed items.

All bills for repairs to foreign cars by Santa Fe shops are sent to the general car inspector's Topeka office. The bills are made and sent on a daily basis. They are checked to determine that each bill is made out properly as to quantities of material and labor and returned for correction if data is not properly billed. Bills that are correct are sent to the Santa Fe's auditor of disbursements, Topeka, for pricing and preparation of the bills which are presented to foreign lines for collection of repair costs due the Santa Fe.

General Material Inspector

THE material inspector department, with Dan Culbertson, general material inspector, Chicago, is responsible for the proper inspection of iron, steel, rubber, leather, canvas, and glass materials, purchased by the Santa Fe for use in repairs, construction, maintenance, and rebuilding. In pursuing those tasks the department is in daily contact with various mechanical offices, the purchasing department and engineering department.

Material included within the scope of the material inspection department is covered by ninety-seven specifications governing the chemical and physical properties as well as other qualifications in regard to surface requirements and sizes, all of which have been developed by the Santa Fe's mechanical department, Also frequently used are material specifications sponsored by the Association of American Railroads, American Society for Testing Materials, American Railway Engineering Association, and the Interstate Commerce Commission.

Fifteen material inspectors complementing the department are located at necessary points throughout the nation. The Santa Fe requires a wide range of materials and products to facilitate its broad operations. Under ordinary conditions material is inspected and tested at manufacturer's plant before being shipped. That procedure insures material having desired properties being received and available for immediate proper use. Records of chemical and physical tests which show the composition of material and strength at the time of purchase, are maintained. In case of failure of material, those original tests are available for comparison by the Santa Fe test department and other interested parties.

Every Santa Fe car built is carefully inspected through all stages of production, both by our own inspectors and those of the car builder. Here Walter Swan, Santa Fe chief inspector at the Pullman-Standard Car Manufacturing Company plant in Chicago, looks over one of the underframes in the order of 64 cars the company is building far our railroad. With him are Al Chimblis, left, assistant foreman, and Herbert Schmidt, foreman of Pullman-Standard.

Lubrication Supervisors

THE Santa Fe has two lubrication supervisors, D. C. Davis, Topeka, in charge of the Eastern, Western and Gulf Lines territory, and C. C. Searle, Los

D. C. Davis (left) and C. C. Searle, lubrication supervisors, with headquarters in Topeka, Kan., and Los Angeles, Cal., respectively.

Angeles, in charge of the Coast Lines territory.

We have noted the detailed attention given lubricating and other oils by the test department in an effort to prescribe proper lubrication for Santa Fe equipment. Lubrication supervisors determine that all established practices are being followed by Santa Fe people engaged in servicing locomotives and cars and that the mechanical features which contribute to efficient lubrication conform with adopted standards.

Efficient lubrication begins with the proper finish and tolerances on wheel and axle work, the boring out and mounting of wheels and turning and finishing journals of axles. With the locomotive, there are numerous movable parts, all fitted to precision and all require special lubricating greases or oils. The metal housing which incloses the journal of a car axle, known as the journal box, receives particular attention, but no less so than engine trucks, trailers, tank boxes and driving boxes. It is important that systematic care be given all journals, bearings, boxes, and wedges and that mechanical lubricators serving locomotive cylinders and valves are functioning properly.

Through Santa Fe trains are serviced at terminals by inspectors and oilers who check all journal boxes and inspect and oil all running gear and journal boxes on locomotives, fill lubricators, and make any necessary minor repairs. Overheated bearings usually are attributed to lubrication failures, but there are mechanical conditions which may contribute to those failures. Whatever the cause, "hot boxes" and accompanying delays are the usual result.

It is important that mechanical features first be correct, and with that sound basis, the preparation and care of journal box packing, its use with oil in the packing process, care by trainmen on the road, and the packing of locomotive engine trucks, trailers, tank boxes and driving boxes in roundhouses and shops, and general care in lubricating the locomotive, he followed through with precision and skill.

The lubrication supervisors instruct Santa Fe people in the proper methods of preparing journal box packing and in the application and servicing of journal box packing to locomotives and cars. They also supervise the necessary tools for that work. They observe the inspection and servicing of journal boxes in train yards and at terminals, make mechanical inspections to find and correct conditions producing hot bearings, further investigating those causes in order that such failures may be kept to a minimum. They also observe the handling and fitting of journal bearings and the reclamation of used journal box packing.

Bill Soffray demonstrating correct way to oil a Journal box.

Power Plant and Electrical Equipment Supervisor and Inspector

THE Santa Fe has approximately eighty-three power plants and heating plants throughout its system lines. Forty-two of those plants are distinct power plants, furnishing steam, heat, electricity, water and air for the operation of Santa Fe shops, roundhouses, and offices, including Fred Harvey hotels and restaurants. The balance of the eighty-three plants consists of small heating plants not contained in separate, distinct buildings, which furnish heat and some power.

The Santa Fe's power plant and electrical equipment supervisor and inspector, B. E. Clark, Topeka, is responsible for general inspection and supervision of those plants. In an emergency, he takes over and operates, as chief engineer, any such plant. To determine if power plant equipment—boilers and combustion equipment, turbines, pumps, air and ammonia compressors, engines, electrical switchboards and other special installations—ate in safe and efficient operating condition, Inspector Clark checks those facilities, educating and instructing engineers, firemen and oilers, assisting with operating difficulties, and locating and correcting methods which cause fuel wastes or other unnecessary expense.

B. E. Clark, power plant and electrical equipment supervisor and inspector, with headquarters in Topeka, Kan.

Santa Fe steam and power plant engi-

The Santa Fe's power plant and electrical equipment supervisor and inspector is responsible, among many other things, for the general inspection of fire prevention and fire fighting equipmerit at roundhouses, shops and terminals. Above is shown the Santa Fe fire house and crew of the Topeka shops.

neers are trained on the job and matters of proper combustion in boiler furnaces, operation and care of power plant machincry, use of power plant instruments and training in repair and maintenance of the latter, must be outlined in detail. Boilers also must be kept clean and safe and properly inspected by local inspectors.

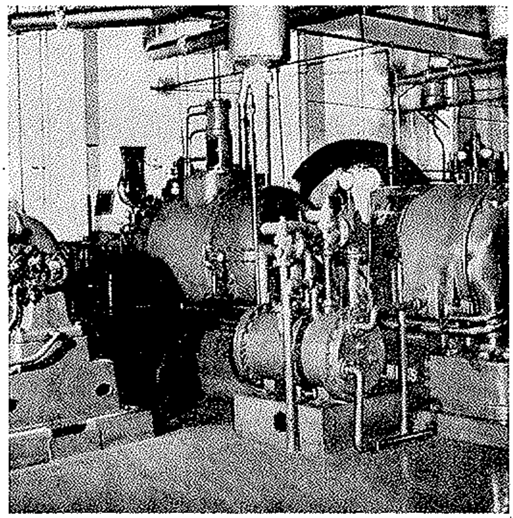
The inspection and general supervision of all locomotive electrical equipment is a further responsibility. Each steam locomotive has a turbo generator operated by steam, and a complete system of electrical wiring, which furnishes electricity for headlights and general lighting, also power for the operation of the locomotive's electrical equipment — train control, automatic boiler water blow-down system, etc. Rules and regulations are exacting. Inspection of those locomotive electrical facilities and supervision of electricians engaged in that class of work, must be thorough. General inspection is given motors and controls on cranes, shop machinery, turntables, and other electrical equipment of Santa Fe shops and roundhouses, as well as pole lines and transmissions, to determine if properly maintained by local electricians.

General inspection also is given fire prevention and fire fighting equipment at roundhouses, shops and terminals. The Santa Fe has Are brigades in various departments at each terminal, trained to inspect and protect Santa Fe facilities from fire. The inspection determines if fire chiefs at terminals are making proper inspection and if fire brigades are properly appointed and instructed. Proper observance of the Santa Fe's *fire rules,* first published in 1923, is emphasized. Those rules are comprehensive and detailed and are not the least of the many worthy practices originating within the Santa Fe's mechanical department.

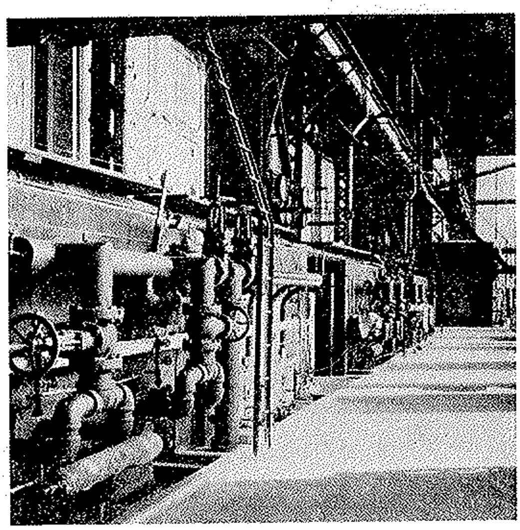
All those duties are concerned with the operation and protection of equipment furnishing power and utilities permitting the servicing and repair of locomotives, cars, and other Santa Fe equipment:.

Chicago, Illinois

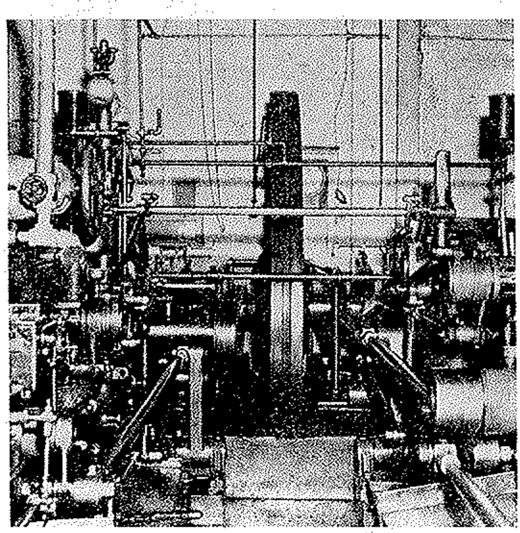
November 30, 1946



Power plant equipment, Albuquerque shops



Boiler roam at Topeka shops



Interior of power plant of Albuquerque shops