kinesthetic signs of direction. . . . It has long been a disputed question as to whether insects are capable of feeling the force of gravity, and this has generally been denied in view of the extremely small weight of their bodies and the comparatively enormous muscular power which they are capable of exerting. It is my good fortune, however, to be able to offer proof that ants are not only capable of perceiving moderate elevations of the terrain by purely kinesthetic means, but that they are also capable in case of necessity, *i. e.* when all other signs of direction are excluded, of orienting themselves merely by this single, meagre kinesthetic engram.

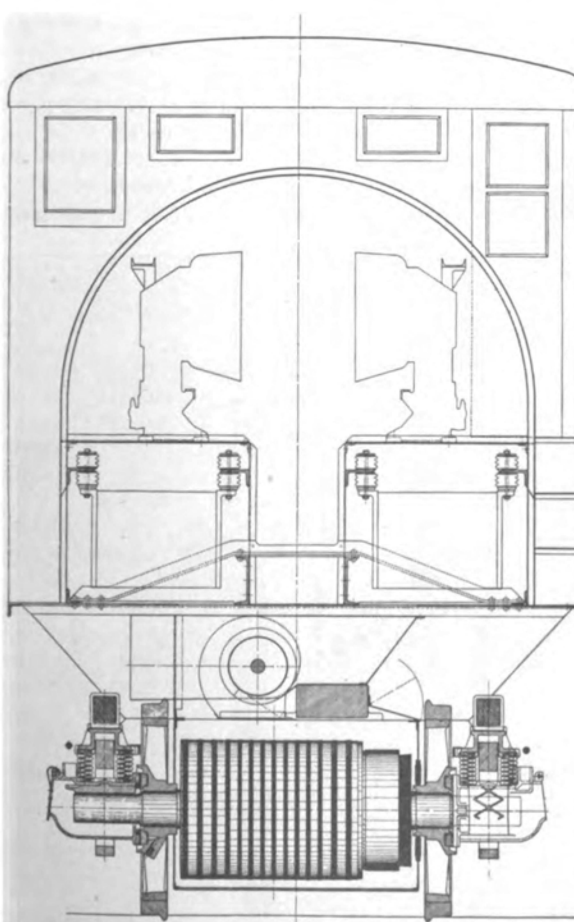
I proceeded as follows: To the edge of my large experimental table I attached an artificial nest containing a small colony of *F. rufa.* The exit tubes of the nest gave upon the top of the table. This table is so constructed that its top can be revolved in every plane of space, and all its axes of movement are exactly centered. In these experiments the table top was inclined at an angle of 20° to begin with in such a manner that the entrance to the nest was at the deepest position. The insects had to crawl upwards to reach the honey which was in a round bowl at the center of the table. Since the experiment was conducted in the dark tent with bipolar lighting described above orientation by light was excluded. I waited till an ant was seated at the feast of honey and then noiselessly changed the slope on the table top to the opposite direction, so that the nest was now above. Having finished his feast the insect started home, but was met by an unexpected puzzle! In all cases the ant first spent considerable time running back and forth undecidedly in both directions for a few centimeters each way, always returning to the honey. (It is interesting to note here the difference between these ants and the *Lasius* of the bridge experiment, which usually ran straight ahead in one direction—the *Formica* seemed on the other hand to be obviously conscious of a dilemma.) Finally, however, in every case the insect decided on a direction, and all of them *ran downwards without exception*, almost exactly to the deepest point, where they described narrowly limited curves for a long time, quite as if they were actually seeking the disappeared entrance to the nest!

Thus they had actually accomplished a virtual orientation by means of gravity! I must forego the citing of many interesting data bearing upon this complex theme. I trust, however, that I have convinced my audience that the distance orientation of ants is an uncommonly complicated phycho-physiological process. . . . Thus comparative psychology has here become an exact science—the comparative physiology of the individual Mnemo.

A Gearless Electric Locomotive

Details of the 3,000-Volt D.-C. Locomotive of the Chicago, Milwaukee and St. Paul Railway

IN the SCIENTIFIC AMERICAN of December 6, 1919, there appeared a narticle on an interesting "tug of war" between a giant electric locomotive and two steam locomotives. Rather it was a push of war for had a pulling test been staged the draw bars of the locomotives could not have stood the strain. In the test the electric locomotive came out victorious even though the steam locomotives were given a head start so as to enable them to attain their maximum horsepower. When the current was turned on the electric unit gradually slowed down the steam locomotives and then pushed them backward with accelerating velocity.



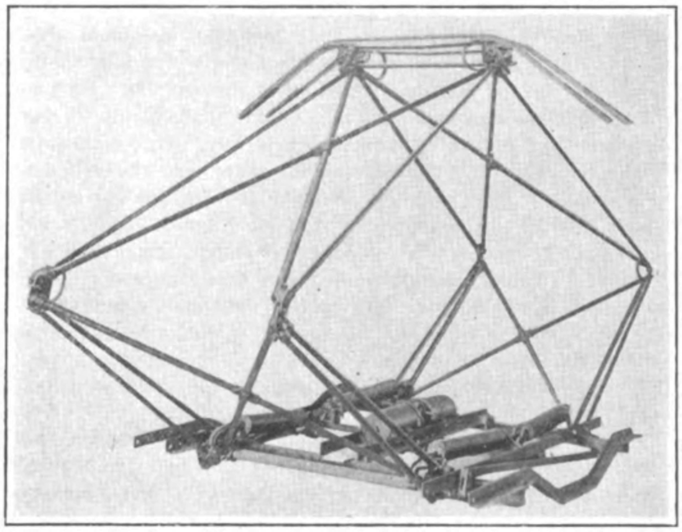
END ELEVATION OF THE GEARLESS LOCOMOTIVE

The big electric locomotive was one of a set of 3,000 volt direct current locomotives that are now being placed for passenger service on the Othello-Seattle-Tacoma electric zone of the Chicago, Milwaukee & St. Paul Railway.

The original electrification from Harlowton to Avery, 440 miles, has now been operating for a number of years under the extremely bad weather conditions of the Rockies and Bitter Root Mountains and, as a result of its unqualified success, the same system will now be used to meet the severe grades and snow conditions of the Cascade Range. The entire equipment for the original electrification was manufactured by the General Electric Company including substations and locomotives. The motive power consisted of 42 locomotives for freight and passenger service and four switchers. Of this original equipment, the freight and passenger locomotives were practically the same and differed from each other only in the gear ratio between motors and driving axles.

The new locomotives are an entirely different design, built distinctively for passenger service and possess some very interesting mechanical and electrical features. They will be used on the new Cascade electrification strictly for passenger service and the present passenger engines will be adapted for freight service by changing the gear ratio. The locomotives are of the bi-polar gearless type, with motor armatures mounted directly on the driving axles. In this fundamental feature, they follow the design of the gearless locomotives in use on the New York Terminal of the New York Central Railroad, which have given remarkable operating results during the past ten years. The chief advantage of this method of construction is the great simplicity of mechanical design which eliminates all gears, armature and suspension bearings, jack-shafts, side-rods or other transmitting devices. The remarkably low cost of maintenance of the New York Central locomotives over the entire period is attributed largely to the gearless type of construction.

The new Chicago, Milwaukee & St. Paul locomotives weigh 265 tons with 229 tons on drivers. They have fourteen axles.



TYPE OF PANTAGRAPH USED ON THE NEW GEARLESS LOCOMOTIVE

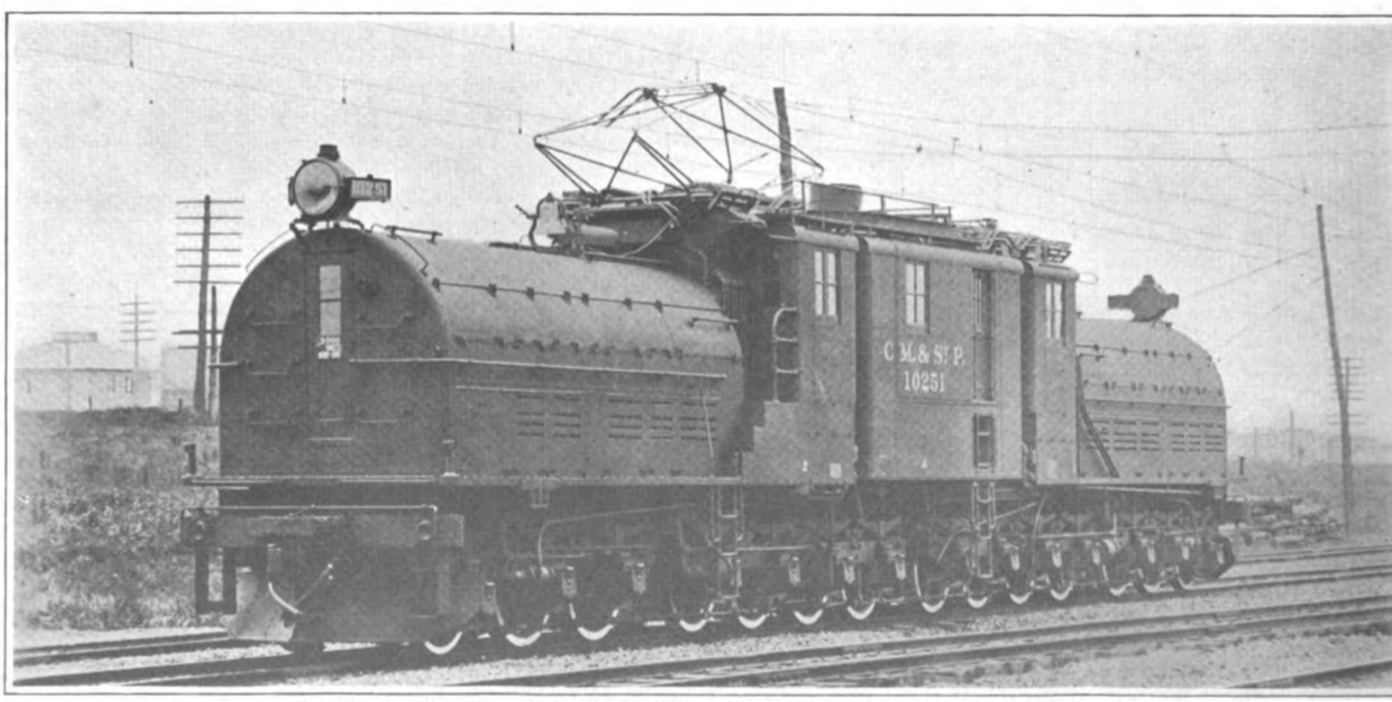
twelve of which are driving and two guiding axles. The weight of the armature and wheels is the only dead weight on the track and this is approximately 9,500 pounds per axle. The total weight on drivers (458,000 pounds) is 86 per cent of the weight of the locomotive but, being distributed among twelve axles, results in a weight of only 38,166 pounds per axle.

One of the most interesting and important features of the locomotive is the design of the leading and trailing trucks and the method of suspension of the cab weight upon them. The successive trucks are coupled together in such a way as to deadbeat or break up any lateral oscillations which may be caused by inequalities of the track. The weight of the main cab is so supported on the front and rear trucks that any lateral thrust or kick of the leading or trailing wheel against the track is cushioned by the movement of the main cab, which increases the weight bearing down on the wheels at the point where the thrust occurs, and automatically reacts to prevent any distortion of the track. The result of this design is such as to give riding qualities at high speeds which have probably never been attained before in a double-ended locomotive. Exhaustive tests on the General Electric Company's test tracks at Erie, Pa., have demonstrated the remarkable riding qualities of the new locomotive at speeds as high as 65 miles per hour which is the limit of speed on the length of test track available. These tests also indicate that the locomotive will operate at much higher speeds with equal success.

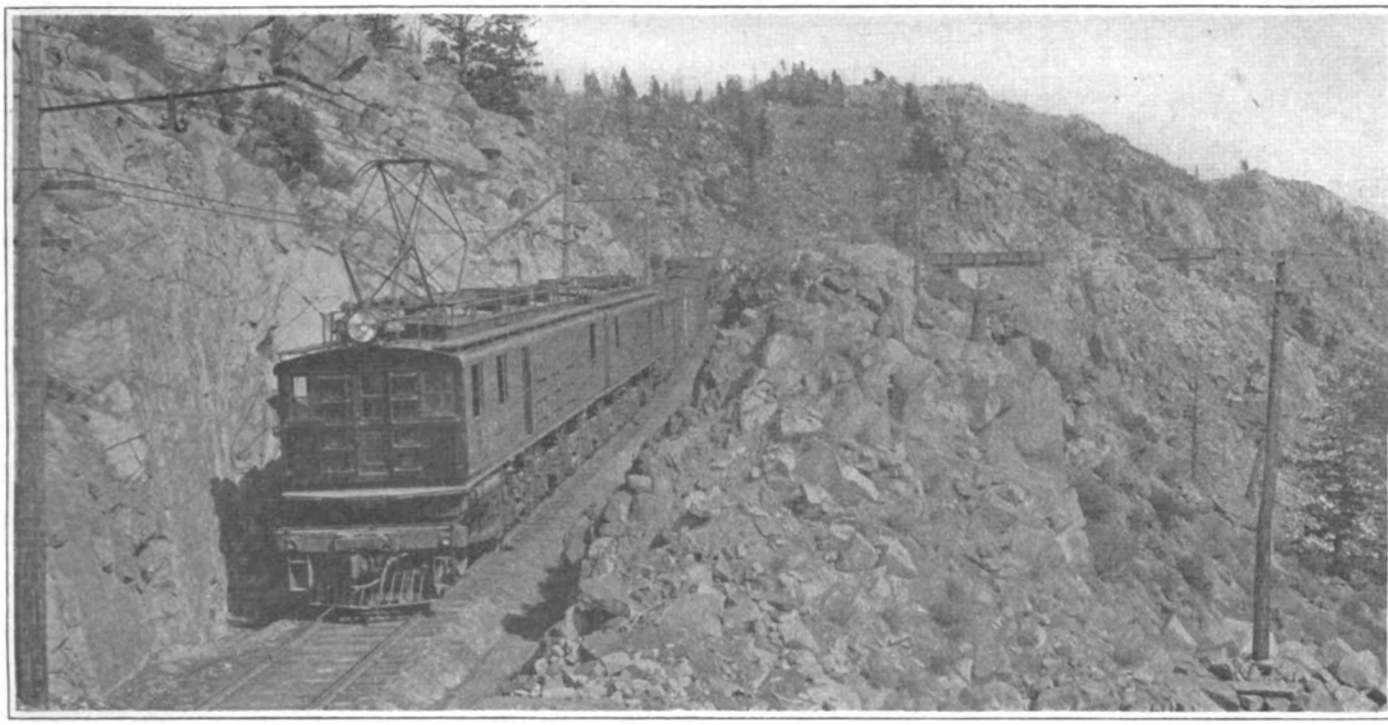
The locomotive is designed for handling in normal service a 12-car train weighing 960 tons trailing against a grade of 2 per cent at 25 m.p.h. This performance requires 56,500 pounds tractive effort which is equivalent to a coefficient of adhesion of 12.3 per cent of the weight upon the driving axles. The wide margin thus provided between the operating tractive coefficient and the slipping point of the wheels, as well as the ample capacity of the motors, will allow this locomotive to haul trains with as many as fourteen cars in emergencies. For continuous operation, the locomotive is designed to operate at 42,000 pounds tractive effort at a speed of 27 m.p.h.

The total weight supported on driving axles is practically the same as that on the present geared passenger locomotives, weighing a total of 300 tons. The table below gives the principal dimensions, weights and capacity of the gearless locomotive:

Length inside knuckles	76 ft. 0 in.
Length over cab	68 ft. 0 in.
Total wheel base	67 ft. 0 in.
Rigid wheel base	13 ft. 11 in.
Diameter driving wheels	44 in.
Diameter guiding wheels	36 in.
Weight electrical equipment	235,000 lb.
Weight mechanical equipment	295,000 lb.
Weight complete locomotive	530,000 lb.
Weight on drivers	458,000 lb.
Weight on guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Number of motors	12
One hour rating	3240 h.p.
Continuous rating	2760 h.p.
Tractive effort—1 hour rating	46,000 lb.
Tractive effort—continuous rating	42,000 lb.
Tractive effort—2 per cent ruling grade with 960-ton train	56,500 lb.
Coefficient of adhesion ruling grade	12.3 per cent
Starting tractive effort—25 per cent coefficient of adhesion	115,000 lb.
Rate of acceleration starting 2 per cent ruling grade	0.48 m.p.h.p.s.



THE 3000-VOLT D.-C. GEARLESS PASSENGER LOCOMOTIVE, WEIGHT 265 TONS



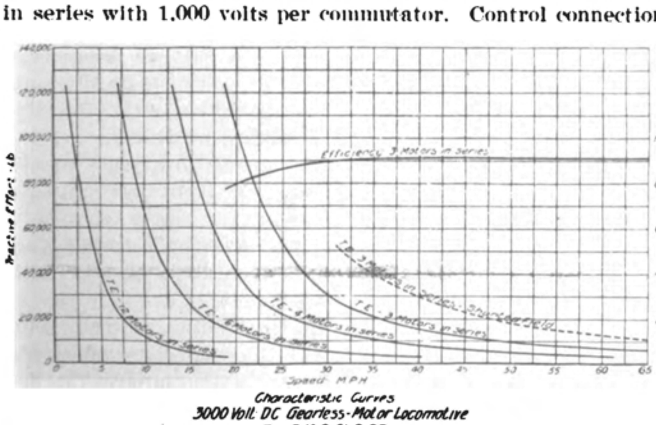
A WEST-BOUND FREIGHT TRAIN, NEAR GRACE, ON A 2% GRADE—55 CARS, WEIGHT 1,450 TONS

The control equipment for the new locomotive is similar in most respects to that used on the original locomotives which have now been operating nearly four years. Modifications were, of course, necessary to comply with the different arrangement of motors. Advantage is taken of a new scheme of connections by means of which four of the main locomotive motors are utilized to furnish exciting current during regeneration, thus reducing the size of the motor-generator set used for control, accessories and train lighting. An appreciable reduction in the weight of control equipment is obtained, at the same time providing for effective regenerative electric braking on the down grades. The motor-generator set furnishes control current for operating the contractors and for charging an 80-volt storage battery which supplies lights and power for the accessory apparatus. The battery is, in general, similar to those used on the passenger coaches. The master controller is constructed in three sections arranged for both motoring and regenerating, all of the cylinders being suitably interlocked to prevent incorrect manipulation.

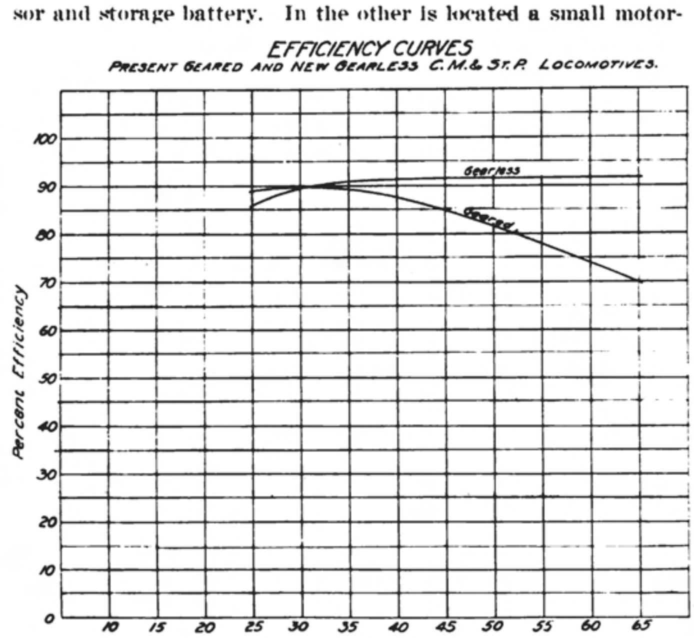
The motor is bipolar, two fields being supported upon the truck springs with full freedom for vertical play of the armature between the pole faces. On page 57 is shown an outline of the locomotive and one of the motors in section indicating the location of the armatures and the magnetic section. For full speed operation, the twelve motors are connected three in series with 1,000 volts per commutator. Control connections are also provided for operating four, six or twelve motors in series. Additional speed variation is obtained by tapping the motor fields in all combinations. Cooling air for each pair of motors is supplied by a small motor-driven blower. This arrangement avoids the heavy duct losses encountered with a single large blower.

As may be seen from the curves herewith, the gearless locomotive shows a much better efficiency at high speeds than the geared type owing to the elimination of the gear drive. In passenger service, where there are long stretches of level track and stopping points are comparatively few, a much higher efficiency is obtained in all-day service. These curves show an efficiency at 50 miles per hour approximately 10 per cent higher than the geared type of locomotive.

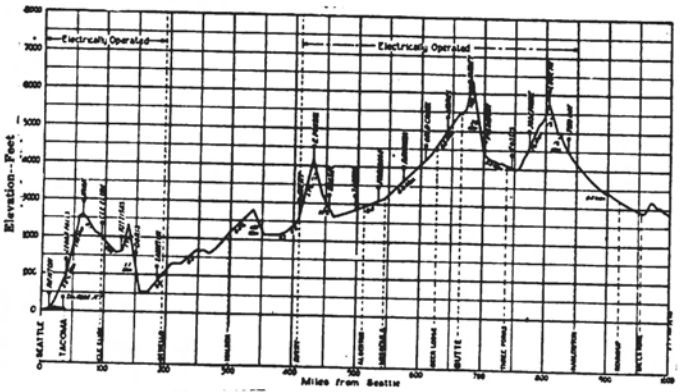
The 3,000-volt contactors and grid resistors are mounted in the curved end cab at each end of the locomotive. In one of these cabs there is also located the 3,000-volt d-c. air compressor and storage battery. In the other is located a small motor-



CHARACTERISTIC CURVES OF THE GEARLESS LOCOMOTIVES



EFFICIENCY CURVES ON GEARED AND GEARLESS LOCOMOTIVES



PROFILE OF THE ELECTRIFIED DIVISION OF THE CHICAGO MILWAUKEE AND ST. PAUL RY. FROM HARLOWTON TO THE COAST

generator set and the high speed circuit breaker. The operating cabs contain the master controller, indicating instruments, and a small air compressor (in No. 2 cab) operated from the battery circuit with sufficient capacity for raising the pantograph when first putting the locomotive in operation. Near the controller are the usual air brake handles for standard braking equipment.

The center cab is occupied by the oil-fired steam boiler for heating passenger trains with accessories including tanks for oil and water, circulating pumps and a motor-driven blower for furnishing forced draft. A slider pantograph, similar in construction to those now in use, is mounted on each of the operating cabs. This pantograph has two sliding contacts, giving a total of four points per slider with the double trolley. The pantograph and flexible twin trolley construction enable the locomotives to collect currents as high as 2,000 amperes at speeds up to 60 miles per hour without noticeable arcing at the contact points. The second pantograph is held in reserve as a spare. Sand boxes, with pipes leading to each pair of driving wheels, are located directly beneath the pantograph outside the operating cab.

The diagram above gives a profile from Seattle to a point about 1,000 miles east, including the Cascade electrification, the Harlowton-Avery electrification and the intervening 220 miles. The new locomotives will operate over the section between Othello, Seattle and Tacoma, including 17 miles of 2.2 per cent grade from the Columbia River west and 19 miles of 1.7 per cent grade between Cedar Falls and the summit of the Cascades. The traffic over this division consists of the heavy main line transcontinental passenger trains "Olympian" and "Columbian," carrying from 8 to 12 steel passenger coaches which will be handled over the maximum grades without helpers. Freight pushers are already in operation on the 2.2 per cent grade, using two of the locomotives from the original electrification. It is expected that electrical operation during the present winter will assist in overcoming many of the delays which are commonly met with during winter operation in this district.

CONCRETE FUEL OIL RESERVOIRS.*

By H. B. Andrews.

Until recently steel containers have been used generally for fuel oil. Concrete had not been considered as a suitable material due to lack of evidence and knowledge of its possibilities. But the practical elimination of steel plates during the war forced the use of a substitute, and reinforced concrete has proved to be satisfactory in many ways, if intelligently handled.

For example: It is necessary to install most fuel oil reservoirs underground, but steel tanks rust if not protected. Concrete can be designed better to resist exterior stresses, as hydrostatic or earth pressures. It has the dead weight better to resist upward hydrostatic pressure in soils which often are filled with water. It does not attract lightning like steel, nor if properly constructed is it affected by electrolysis. It is a non-conductor of heat and cold, thus retarding evaporation of oil in summer, and also retarding the lowering of temperature of the oil in winter—an advantage in pumping. In case of a conflagration the oil is much safer in a concrete container than in steel.

But as previously stated, oil reservoirs of concrete must be designed correctly, the concrete proportioned correctly and mixed and placed correctly in order to get satisfactory results. And by satisfactory results it is meant that there shall be no leakage or seepage when built or thereafter to cause fire hazards or financial loss.

When these necessities have been provided for, reinforced concrete reservoirs will contain fuel oil of a consistency up to 40° B., and practically all fuel oils are below this, the Mexican oils having a specific gravity as low as 16° B. For the lighter oils, including kerosene, gasoline or benzine, some provision should be made for a lining of special material, and the writer understands that the U. S. Shipping Board has been making some extensive experiments along this line.

The design and the location of a fuel oil reservoir may be considered from various standpoints.

(1) Location. The reservoir should be located a safe distance from inflammable structures as far as possible consistent with pumping requirements, covered with at least 16 inches of earth, if near buildings, to decrease fire hazards and also to minimize oil evaporation. If distant from buildings it should be at least half underground, and if possible, the excavated material should be used in banking up around it.

(2) Size. The reservoir should be limited in size for two reasons: First, the necessity of not exceeding a day's working limit in operation of pouring concrete so that joints between operations may be eliminated and secondly, so that in case of an accident or fire in any reservoir, that too much oil in storage will not be involved. This size limit should not be over 300,000 gallons under most conditions, and the majority of contractors have not the facilities to construct properly a reservoir of this capacity.

(3) Shape. The reservoir should be circular in shape, the better and more directly to take care of involved stresses and to avert danger of tensile or temperature cracks.

(4) It should be so proportioned and designed as to limit the number of pouring operations of concrete, so as to avoid joints between these operations.

(5) Care should be taken to provide for all exterior stresses, such as hydrostatic pressure from ground water, earth pressure on walls, and roof if reservoir is buried, and also to avoid as far as possible concentration of loads on walls or footings. Where joints are absolutely necessary to so protect these joints that there will be no leakage through them.

Regarding hydrostatic pressure, while engineers have found from tests that this pressure in soils is only about 50 per cent of the full head of water, it is not safe to design for stresses less than the full head, as any deflection in the concrete admitting a film of water between the earth and the concrete will produce the full hydrostatic pressure.

(6) To so design the reservoir, piping and vents as to comply with municipal regulations and insurance requirements.

(7) To protect temporarily or permanently concrete surfaces so that oil will not come into immediate contact with them if concrete is less than six weeks old.

(8) To so design the false work for holding concrete temporarily in place that it will not fail or be distorted while placing concrete. It is especially necessary to provide for the firm holding of wall forms, as the pressure of several feet of concrete poured quickly as a monolith, is intense, and any give of the forms after the concrete has obtained its initial set breaks up the crystals already formed, allows ex-

*From *Oil News*.