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Expansion Programmes of Railway Workshops in the Second Five Year Plan

THE Railway Workshops Expansion Plan as a part of the Second Five Year Plan of the Railway Ministry is of the magnitude of Rs. 65 crores and now in the month of June/July is still at the drawing board stage.

Although new Workshops are being planned and old ones modified and expanded at the expense of many crores of rupees, very little has yet been finalised.

The fabrication of steel for the new Workshops themselves, the preparation of the sites with roads, drainage, power, water supply and housing for the labour and management will take the good part of three years or more.

The same length of time will be taken to finalise the machinery programme, draw up the specifications, call for tenders, select the machinery, order it and finally have it imported into the country, erected and put into service. With such a late start it can hardly be expected that the targets will be fulfilled even in spite of the best efforts of Railway men, both high and low.

The Workshop Plan has for its basis the Five Year Plan for Railways which anticipate the growth of passenger traffic by 15% and an increase in goods traffic by 51%. To meet with this increased traffic more locomotives, more carriages and more wagons will be required and this means that an additional load of fairly large magnitude will be thrown on the Workshops for repairs and overhauls.

The existing workshops of Railways were designed at a time to meet certain load of traffic and the number of locomotives, carriages and wagons were based on the traffic offering at that time and although the planners of those Workshops had left room for expansion they never anticipated the tremendous growth of Railway Traffic as it is today and consequently our Workshops have been growing in a haphazard manner. At first the space that was left in order to allow men to work freely with machines and other types of equipment was encroached upon by inserting new machines, closer to the old ones than was originally intended and when even this failed then additional leantos and sheds of odd dimensions were constructed to meet with what was considered to be a temporary expansion. However, the increase in traffic went on and the Workshop capacity was found totally inadequate to meet the present loads but with a war intervening the evil day of expansion was postponed.

In some cases due to the partition of India, some Railways had to work with hardly any Workshops at all and had to depend upon the Workshops of other Railways to meet the demand for repairs and maintenance.

Now that the time has come for real expansion and the construction of new shops, foresight and vision is necessary in order to plan both the expansion of the existing shops and the construction of new shops not only to meet the increase in traffic as visualised in the next Five Year Plan, but possibly further increase in traffic, both passenger and goods, in the subsequent Five Year Plans.

For expansion of existing Workshops if space permits and in many cases space does permit, it is better to build new Shops and spread out the machinery, plant and equipment so that adequate room is provided for workers for the handling and assembling of parts required for locomotives, carriages and wagons.

The Railway Workshop work of to-day can be divided into two parts :—

(a) The manufacture of spare parts on a mass production basis for Stores and

(b) The repairs of material as it comes from the Rolling Stock in sufficient time to put back again on to the same.

Opportunity, therefore, should be taken during this Five Year Plan to separate as far as possible the Manufacturing Shops from the Repair Shops in order that an increase in out-turn may be obtained from the manufacturing shops with incentives for greater production and by selecting the best type of workers with skill and knowledge for the manufacturing side.

It is the manufacturing side that is the weak link for the adequate overhaul of rolling stock and if sufficient spare parts were always available the number of shopping days for repairs and overhaul could be reduced considerably so that more items of rolling stocks could be made available for traffic rather than be held up in the shops.

With regard to new Shops, these are necessitated by the increase in rolling stock which will be held by the various Railways and that increase will possibly go still further into the next Five Year Plan.

In planning these new shops, therefore, most modern planning ideas should be incorporated. We have adequate examples of workshop planning in our two modern shops at Chittaranjan and Perambur, where the bays are 75′ wide and there is ample room for expansion both inside and outside the shop.

In order to speed up repair work ample craneage facilities are of paramount importance and in planning these shops, these facilities should be provided within liberal limits in order to give the maximum facility for quick disposal of repaired material and erection work.

With regard to new machinery, there has been continuous improvement in design and manufacture of new machines, but for every improved design incorporated in a machine the price factor is relatively increased. It is, therefore, not of much use to go in for machines with all push button control and quick acting facilities and then to hand such high precision and highly equipped machines to men of inadequate training because of the possibilities of expensive machines being ruined in the first few years of their service due to careless handling and inefficiently trained staff. Machines robust in construction and fulfilling the requirements for mass production with the use of Cemented Carbide tools etc. should be selected in preference to delicately controlled machines which are likely to give considerable amount of trouble in their maintenance in the long run.

In locating these new machines in the new Workshops care should be taken to avoid long leads for the machining of work pieces after each operation. Modern production techniques are eventually bringing to notice how much increase in production could be effected by having the machines in such a position that long leads and transport are avoided.

All ancillaries required in the correct performance of the various operations should be provided in a liberal measure. Workshop staff are now so used to labour saving devices that adequate provision must be made for Pneumatic Power, Hydraulic Power, Electric Power, Welding and Cutting facilities and internal transport. While it is admitted that there is the possibility of wastage of this power because of inadequate maintenance in the long run, much physical labour and fatigue will be avoided and manufacture and repairs could be speeded up with the use of these types of power.

In the Workshops themselves adequate racks for the storage of material which is drawn from the stores and other materials which comes off the rolling stocks for repairs should be provided and as far as possible shabby habits of flinging material on the ground or storing it under benches and by the side of cupboards should be discouraged.

All shops must be provided with adequate weather protection devices, which will allow plenty of sunlight, without glare, ventilation and drainage to meet the conditions of heavy monsoon rain where such occurs. It is found that many of the existing shops which are exposed to weather conditions, ruin both the machines and equipment and interfere very seriously with the production of workshops.

While all this planning of new shops and expansion of old ones and procurement of machinery are of great importance, expansion of shops will demand the employment of additional staff and it is essential that the efficiency of our workmen be raised by proper training facilities and refresher courses. Adequate accommodation must, therefore, be provided for practical training on a large scale and visual instructions in the form of cinemas of technical films showing how repairs and maintenance is carried out in more advanced countries abroad.

It is essential that every anna of the Tax payers' money is put to the best use and that purchases and expansions are made to meet immediate requirements and for still further expansion when the need arises.

Non-destructive Methods of Testing Civil Engineering Materials

By K. R. Rao*

NON-DESTRUCTIVE methods of testing materials have become widely popular in a number of industries. The main aim of any non-destructive test is to evaluate the quality, strength, discontinuities or serviceable properties of the materials, structures, etc. without damaging the test object. The advantages of these methods over the usual destructive methods are well known. However, a word of caution about their limitations is necessary in order to apply them in a more effective way. The main disadvantage of these tests is that they require considerable skill, experience and judgment on the part of the user. Secondly, as most of the non-destructive methods, determine strength and serviceability, by indirect procedures, a necessary pre-requisite, is a well established correlation between the property actually measured by the test and the strength or serviceability property that is predicted. Often there is a misconception, that a single non-destructive test, measures all the properties. Non-destructive tests are specific to certain types of materials, conditions and defects. A single job may need different non-destructive tests for different materials and more than one type of non-destructive test may be required for complete inspection of a single test object.

The usual non-destructive methods, that are in wide application in metal testing, are, X-ray and R-ray radiography, magnetic surface inspection, fluorescent penetrating liquid (surface) tests, and ultrasonic methods. A good deal of literature has been published on these methods. In this paper, the recent developments in extending the ultrasonic and R-ray techniques in the field of testing materials of Civil Engineering interest, are described in some detail.

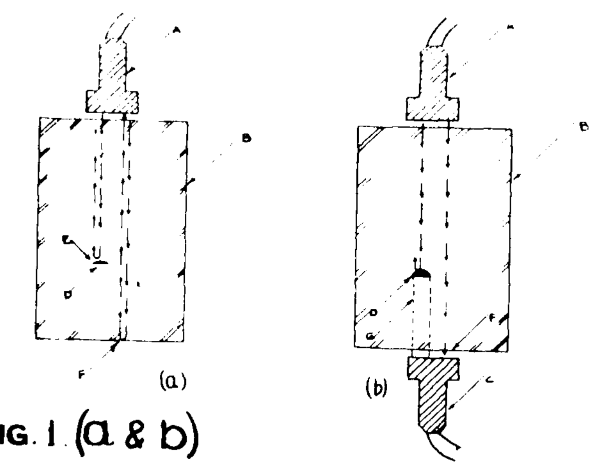

FIG. 1 (a & b)
ULTRASONIC TESTING BY REFLECTION & TRANSMISSION METHODS.

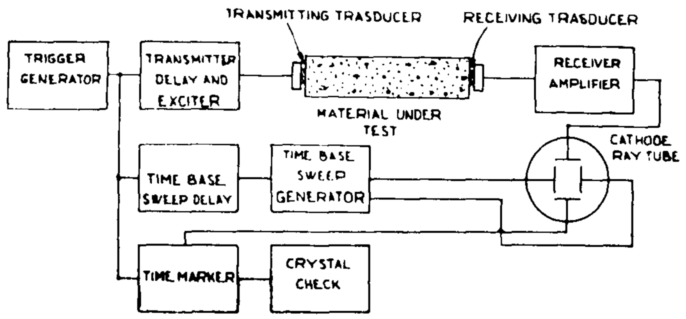

FIG. 2:- SCHEMATIC DIAGRAM OF THE ULTRASONIC PULSE TESTER.

ULTRASONIC TESTS

X-rays and R-rays have penetration ranges of approximately 6 inches in steel, and they cannot be used for the detection of flaws in greater thickness, which are frequently encountered in practice. In recent years ultrasonic methods have provided a solution to this problem. Though the principle of the application of these test methods to the civil engineering materials, like, concrete, stone, wood, soil etc. is the same as in the case of metals, the requirements of the instrumentation differ widely depending on the internal structure of the materials under test.

THEORETICAL CONSIDERATIONS

Ultrasonic waves are elastic waves with frequencies above the audio range, and their velocity in any solid is dependent upon the type of vibration, the physical constants and the grain structure of the material. There are three types of wave propagation, that are encountered in a body, namely longitudinal, transverse and surface waves. The longitudinal and transverse waves are generally associated with the bulk of the medium, while the surface waves are confined to the surface or the boundary of the medium [1), 2)].

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Assuming the dimensions of the medium to be infinite, the velocity of a longitudinal wave "V_L" is a function of the density "ρ," modulus of Elasticity "E" and poisson's ratio, "σ" of the material of medium. These factors are related by the formula

$$V_L = \sqrt{\frac{E}{\rho}\,\frac{(1-\sigma)}{(1+\sigma)\,(1-2\sigma)}} \qquad \text{—(1)}$$

In a finite solid, the primary or axial waves set up lateral waves which will reflect back from the boundaries and cause destructive interference with the primary waves and reduce the velocity of the primary wave. Thus the formula reduces to the form;

$$V_L = \sqrt{\frac{E}{\rho}} \qquad \text{—(2)}$$

This is not the exact expression of V_L, for solids of finite dimensions, as further corrections[3)] based on considerations of poisson's ratio, harmonic interference, internal friction and the heat conductivity of the material are to be effected.

Transverse waves are little affected by physical dimensions of the medium, and their velocity "V_T" may be computed from the equation

$$V_T = \sqrt{\frac{E}{\rho\times 2\,(1+\sigma)}} \qquad \text{—(3)}$$

Surface wave velocity "V_S" is calculated by multiplying V_T by a constant "α" which is a function of the poisson's ratio. The equation for surface wave velocity is therefore given as

$$V_S = \alpha\sqrt{\frac{E}{\rho\times 2\,(1+\sigma)}} \qquad \text{(4)}$$

The ratio of the longitudinal and transverse waves in the testing media will depend on the poisson's ratio. Thus the poisson's ratio of the material could be obtained from the equation

$$\frac{V_L^2}{V_T^2} = \frac{2\,(1-\sigma)}{(1-2\sigma)} \qquad \text{—(5)}$$

ENERGY DISTRIBUTION

Considerations of sensitivity for the detection of discontinuities in the testing materials are dependent upon the distribution of energy of the ultrasonic beam. It can be readily understood that a more concentrated or less divergent beam will bring more energy to bear upon the surface of discontinuity, thus giving rise to more prominent indication of its presence. The energy of an ultrasonic beam in a crystal is maximum at points along the axis normal to the crystal face and decreases on either side of the axis, and is given by the expression

$$\sin\alpha = \frac{1.2\,\lambda}{D} \qquad \text{—(6)}$$

where "α" is the half angle of the apex of the conical beam.

D is the diameter of the surface.

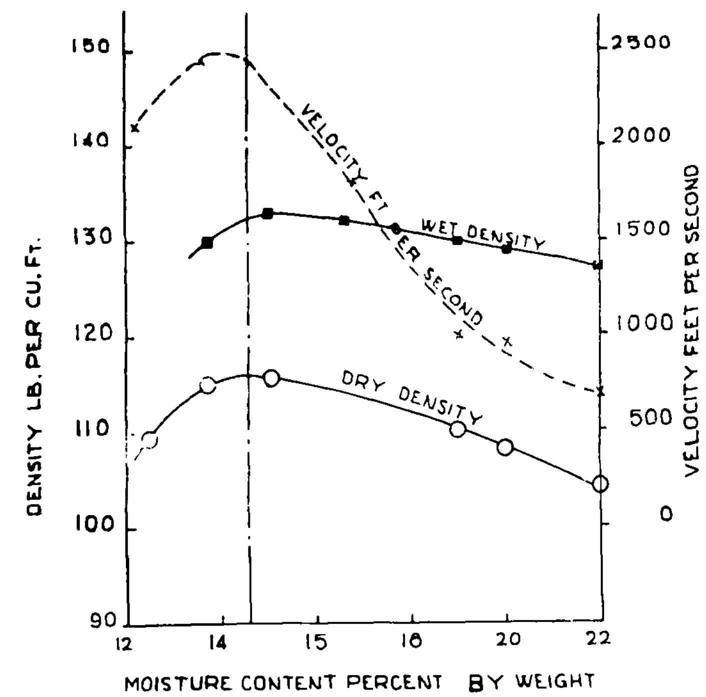

FIG. 3:- VELOCITY VERSUS MOISTURE CONTENT & COMPACTION IN CLAY

λ is the wave length of the ultrasonic wave emitted.

The use of shorter wave lengths and sources of larger diameter concentrate the energy of the beam to a tighter cone.

EFFECT OF THE INTERNAL STRUCTURE OF THE MATERIAL ON THE TRANSMISSION OF ULTRASONIC ENERGY

The concept of acoustic impedance natching and reflection of energy are of considerable importance to the passage of ultrasonic waves through a medium. The structural variations and voids in the material also give

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rise to reflections and scattering of the ultrasonic beam. When the size of the grains of a material is sufficiently large in relation to the wave length of the ultrasonic wave, it is difficult, if not impossible, to pass the wave energy through the material. The internal structure of the material may exhibit directional properties i. e., different velocities in different directions. Thus the frequency should be chosen to suit the size, surface conditions and the internal structure of the object to be tested. If the surface is smooth and the material is fine-grained and homogeneous, higher frequencies give the best results while lower frequencies may be more advantageous, for a materials with coarse-grained structure and greater thick sections.

PRACTICAL ASPECTS

With the foregoing theory of the propagation of ultrasonic waves in materials one can better appreciate the practical aspects of testing materials by ultrasonic methods. Inspection by means of ultrasonic vibrations involve three basic steps, namely the introduction of wave into the material, the detection of the wave after it has traversed the material and the interpretation of the change in the wave amplitude and velocity when passing through the material[4]. Piezoelectric crystal transducers are generally used for transmitting as well as receiving the ultrasonic waves.

Longitudinal waves are generally used in ultrasonic testing because their generation as well as detection is easy.

There are three types of ultrasonic methods of testing of materials (1) Reflection method, (2) Transmission method and (3) Resonance method. The first two methods are more popular than the third one.

REFLECTION METHOD

By this method the discontinuities in the material under test can be studied. This is illustrated by Fig. 1(a). This method has a special advantage in the cases where only one surface of the test object is available. Moreover, by this method tests can be carried out with only one transducer which acts both as transmitter and detector. The amplitude of the reflected signal and the time taken to travel upto the flaw and back to the detector, indicate the magnitude and the location of the flaw.

TRANSMISSION METHOD

This method gives the wave velocity of the ultrasonic pulse in the material from which the elastic properties can be computed with the help of the equation (1) In this case the presence of a discontinuity is indicated by the attenuation of the transmitted wave. This illustrated by Fig. 1(b).

GENERAL FEATURES OF INSTRUMENTS

The general arrangement of the circuits of an ultrasonic apparatus for transmission method is shown by the schematic diagram Fig. 2. The functions of the different circuits are as follows :

The trigger generator produces a negative rectangular pulse at a repetition frequency of 50 pulses per second, from the leading edge of which the transmitter, and time marker circuits are all triggered. The transmitter variable delay unit generates a rectangular pulse which can be varied over a range of 10 microseconds and triggers transmitter exciter. An ultrasonic pulse, consisting of a train of longitudinal waves, result from the shock excitation of a piezoelectric crystal transducer which is coupled to the material under test by a thin film of oil. A similar piezoelectric transducer is used to receive the ultrasonic pulse after travelling in the material. The received signal is fed through a high gain amplifier to the vertical deflection plates of a cathode ray tube. The time base sweep, delay and the time

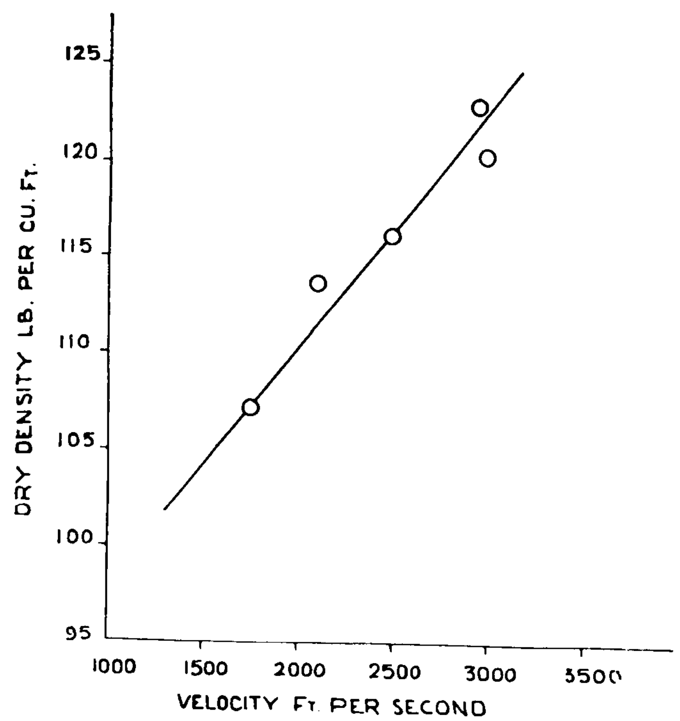

FIG. 4 :- VELOCITY VERSUS DRY DENSITY IN SILTY CLAY.

marker circuits will enable to measure accurately the time taken by the ultrasonic pulse to travel through the known length of the material. From this data the wave velocity of an ultrasonic pulse in the medium can be calculated. There are several instruments available wherein different circuits have been used. Nevertheless their basic principles are the same.

ULTRASONIC PULSE TECHNICS APPLIED TO CONCRETE, WOOD AND SOILS

Since the propagation of ultrasonics is dependent upon the elastic constants of the material, it is possible to calculate the moduli of elasticity of concrete and other materials in the field.

CONCRETE

There is an upper limit to the frequency which can be used for testing concrete due to the increased attenuation of vibrations when the wave length becomes comparable with the size of the coarse aggregate in the concrete. 200 k c/s is suitable for use in concrete upto 2 ft. thick when the maximum size of the stone aggregate is about ¾ inch and the wave length is about 1 inch. For longer paths it is necessary to use lower frequencies. With 60 k c/s, 8 ft. range is obtained whilst with 20 k c/s, the range can be extended to 50 ft.

Attenuation of the ultrasonic waves also depends on the quality of the concrete, the loss of energy being greater in porous concrete than in well compacted one. The amplitude of the received signal will also provide an indication of the quality of the concrete being tested.

The concretes tested are generally categorised as "known" and "unknown" depending upon whether its history is known or unknown. In the case of unknown, concrete no strictly accurate assessment of the quality can be derived from the longitudinal wave velocity measurements, though a rough division of good and poor quality is possible.

The method is particularly suitable for studying the variations of quality with time and external influences even for the "unknown" concrete.

It should be realised that a condition which is acceptable in one class of work may be rejected in another class. For example, the minimum velocities accepted for a few specific structures in Great Britain are quoted below[5].

Type of work.	Acceptable minimum value of Longitudinal wave velocity.
1. Prestressed Concrete —T Sections.	15,000 ft./second
2. " " —Anchor Units.	14,300 ft./second
3. Reinforced Concrete frame Building.	13,500 ft./second
4. Suspended floor slab.	15,500 ft./second

To determine the relationship between the longitudinal wave velocity in the concrete and its quality it is essential to study the changes produced in the velocity by the changes in those quantities which determine the quality of the concrete as measured by the compressive strength, modulus of rupture and density.

A number of workers [6][7][8] have attempted at developing formulæ for the relationship between the dynamic Young's Modulus "Ed" and Compressive Strength. It was felt that the general form of the formula may be given as below :

$$Ed = K.n\sqrt{R} \qquad \text{—(7)}$$

Where "R" is the compressive strength

"K" and "n" are constants.

Some of the investigators hold the opinion that it is preferable to find a relationship directly between the measured pulse velocity and the compressive strength instead of dynamic modulus of elasticity, which is computed from the velocity of the ultrasonic wave, and compressive strength.

Some investigators have tried to correlate to the static modulus (Es) and the dynamic modulus (Ed) calculated from the pulse velocity measurements. The results do not appear to be conclusive.

It is an observed fact that there is no unique pulse velocity for a particular compressive or transverse strength of concrete. The concretes which had the same compressive strengths did not always give the same longitudinal wave velocities. The type of aggregate and the aggregate cement ratio effect the velocity to a great extent. However, for any concrete of known history it is possible to establish correlation between the velocity of the ultrasonic wave and the compressive strength. This method also makes possible to ascertain the variation in the quality of any concrete "known" or "unknown" in a structure with service and time.

It was pointed out that the presence of large sized aggregate in concrete renders it heterogenous. However, when the part in the concrete is long, the material may be considered as homogeneous from statistical point of view. Another assumption to be made in these tests is that the concrete is isotropic for all practical purposes, which does not appear to be true.

A number of investigators [5][6] have studied the variations in the pulse velocity in concretes of different mix proportions, water cement ratio, age, and frost and fire damaged concretes. The following are some of the conclusions drawn from these studies.

1. Increase in water cement ratio produces an increase in the number of water voids and decreased the longitudinal wave velocity.

2. Increase in percentage coarse aggregate increases the longitudinal pulse velocity.

3. The relation between the longitudinal wave velocity and modulus of rupture is sensibly independent of the type of aggregate used where as, separate relations exist between the longitudinal wave velocity and compressive strength for each type of aggregate. It appears that there is a law of proportionately for the dynamic modulus of elasticity of the concrete and its constituents. This relationship is given as below :

$$E_c = E_{gr} \times g + E_{mo}(1 - g) \qquad \text{—(8)}$$

Ec is the modulus of the concrete.

Egr is the modulus of the gravel.

Emo is the modulus of the mortar.

g is the absolute volume of the gravel.

The resultant modulus Ec is to be modified by a reduction coefficient which takes into account of the voids.

$$\frac{\text{Calculated modulus}}{\text{True modulus}} = \text{Percentage of solid matter of the concrete.}$$

4. It is also possible to determine the setting time of concrete by this method. Final setting of concrete is associated with a rapid increase in the longitudinal wave velocity. After this period the velocity continues to increase at a slower rate.

The variation of Ed with time satisfies the relation.

$$E_n = Eo + b \log t \qquad \text{—(9)}$$

Where E_n is the modulus of elasticity at any age.

Eo is the modulus at the age when the final set takes place.

b a constant for a particular concrete.

't' age in days.

Jones [7] applied this method to study the mechanism of the compression failure of concrete and the crack formation, under compressive and tensile loading. The longitudinal wave velocities in the axial and transverse direction are measured while load is being applied. The onset of cracking was indicated by a marked fall in the velocity in the transverse direction, while the velocity in the direction of loading remained unaltered. This indicates that the internal fracture occurs by cracking parallel to the direction of loading. The first crack indicated by the fall in the longitudinal wave velocity in the transverse direction was noticed at about 30% of the ultimate load. Further increase of load resulted in further decease in velocity. It was also observed that the micro cracks occurred at a stage when the lateral strain is of the order of 10^{-4} which is also the deformation limit of concrete in tension. It may be concluded from these studies that even in compression, the failure is of tensile nature.

It appears from the foregoing discussion that applications of ultrasonic testing methods to concrete have immense value to the structural engineer in the field as well as in the laboratory. These are only of recent origin and much work is still needed in order to realise their full potentialities. However, from the present day knowledge on these tests, it is felt that structural engineers will gradually be prompted to think of the quality of the concrete, not solely in terms of compressive strength but also in terms of ultrasonic wave velocity and dynamic modulus of elasticity.

STONES, WOOD & SOILS

The ultrasonic technique had also been applied to measure the quality of stones used in constructional work and had assisted in detecting the defective areas of rock in the quary. This method is also proving to be a valuable tool in the testing of wood samples. A series of pulse velocity tests were made in the directions parallel and perpendicular to the grain distribution, by Leslie on wood specimens with various amounts of "heart rot" present and found that the defective portions of the wood could easily be located by this method. The velocity also depends on the moisture content and probably on some other factors too.

Ultrasonic tests have also proved to be of considerable use for soil testing in the laboratory as well as in the field. The velocities of ultrasonic waves are found to have a relation with the moisture content and dry density

The velocity is maximum at optimum moisture content of the soil. This is illustrated by Figs. 3 and 4. Thus with the use of control tests in the laboratory the density of the soil compaction in Situ can be measured by this method.

HARDNESS TESTS

Hardness tests like spring hammer, pendulum hammer and indentation tests are also used [9] to assess the strength of the concrete and stones, in the field. A correlation was tried to be worked out between the surface impact hardness, measured by the rebound of the hammer or the indentation of a ball, and the compressive strength of concrete.

It was claimed that these tests are independent of variations in the composition of concrete, such as the type of aggregate, aggregate cement ratio etc. The variation in the results with these tests are large and are of the order of 20 to 30 per cent. Another objection to these tests is that as these tests are limited to the surface, the results will very considerably with the surface conditions of the mortar and need not necessarily be an indication of the interior mass. These tests are not as reliable as the ultrasonic tests. The only advantage of these methods is that the apparatus is much more simple and economical than that of ultrasonic equipment.

GAMMA RAY TESTING OF CONCRETE

Within the last few years the development of atomic energy has led to a considerable progress in the field of non-destructive testing. Many types of radioisotopes which act as sources of gamma rays have been made available by the nuclear reactors. The radioisotopes mostly used in the field of gamma-ray radiography of metals are cobalt 60, Iridium 192 and Thulium 170. The cobalt 60 being a powerful source is suitable for penetration in steel upto 1½" to 10" thickness. The Iridium 192 with its lower energy is used only for ¼" to 2" thickness of steel. Thulium 170 is mostly useful for the examination of aluminium sheets.

Though the application of gamma rays in the field of concrete testing is only of very recent origin this is progressively gaining importance, in the determination of the density and the moisture content of the materials like concrete, bricks, soils etc., in situ. It is also possible to study the effect of vibration on the compaction and seggregation of the concrete with the help of gamma-rays. The new techniques of gamma-ray analysis with microphotometric recording devices increase their applicability in testing building materials.

The basic principle involved in Gamma Ray testing is that the absorption of Gamma rays in a material is proportional to the density and thickness of the material. The relationship is given by the equation

$$I_d = I_o e^{\lambda d} \qquad \text{—(10)}$$

Where λ is a constant for the material

d is the thickness of the material

I_o original intensity is the radiation

I_d is the intensity after passage through a material of thickness 'd'.

If the constant for the material is known, it is possible to calculate the distance $d_{\frac{1}{2}}$ known as the "half value layer" i. e., the distance required to reduce the intensity to half. Every additional half value layer will reduce the radiation by the factor 2. The value of $d_{\frac{1}{2}}$ for concrete using Cobalt 60 is approximately 2 inches. If the material has an air filled void within a thickness 'd' in the direction of the rays, the radiation will pass practically unaltered through the void and the final radiation intensity Id' is higher than the expected intensity Id. The ratio Id'/Id is directly proportional to the void content in the path of the rays. In the case of honeycomb concrete, the change in intensity is proportional to

$d\,(\rho_c - \rho'_c)$ where ρ_c is the density of sound concrete and ρ'_c is of honeycomb concrete. [10]

It is reported that the inspection of concrete with Gamma-rays is feasible only for thickness upto 3 ft. For greater thick sections, however, the required strength of the radioisotope source will become great and the handling difficulties make the technique impracticable. Although the density of the concrete can be determined in situ by this method it does not seem to give any idea of the mechanical strength properties of the concrete. A major advantage of this method is that it can be applied even when the concrete is in a plastic state and thus makes it possible to correct the defects at a minimum expense.

Experiments on the gamma-ray radiography of concrete to locate reinforcing rods, pipes and conduits are also being carried out by some investigators. It was found that a ¼" steel rod could be located upto 10 inches thick concrete.

With the recent introduction of the R-ray sterographic techniques the exact location together with the determination of the magnitude of the flaw in all the three dimensions is possible. Gamma ray testing of materials in the field of flaw detection of building materials and the determination of density and moisture content in situ has a great future in India especially due to the fact that the radioisotopes will be released for testing purposes in the event of the erection of nuclear reactors in the near future.

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EDITOR

Modern methods of Manufacture of Lockwashers and Rail Fastenings

By our "Engineering Correspondent"

IN their factories at Sheffield and at Aycliffe, Darlington, the firm of Toledo Woodhead Springs Ltd. manufacture principally laminated, coil and torsion bar vehicle suspension springs. They have, however, other divisions which are concerned with products in which their great experience in manipulating spring steel plays its part, and which are of interest to the railway track and mechanical engineer. These are the manufacture of spring lockwashers and of spring rail fastenings.

SPRING LOCKWASHERS

Spring lockwashers are made in a plant at Aycliffe which is one of the most up-to-date in the world, having entirely modern equipment, all of it installed in the last few years. This includes special machinery for forming, shaping, hardening and tempering also rust proofing the Lockwashers to customers special requirements. Special packing to customers instructions can be arranged. Complete equipment is available for physical and metallurgical examination of raw materials and for testing the finished product to the maker's or to customers' specifications.

Users of Spring Lockwashers are not always fully conversant with the technical theory of these locking devices, and it may not be out of place here to examine the reasons why this system of fastening will keep bolted assemblies tight when other methods fail. The problem of preventing nut and bolt assemblies from becoming slack under conditions of stress and vibration is a very old one—probably as old as the screw bolt itself. Since a nut, when fully tightened, needs only a slight backward turn of the wrench to loosen the assembly to the 'finger-tight' condition, it is quite natural to assume that a nut loosens under vibration because of such a backward turning on its bolt. The problem of keeping it tight was therefore assumed to be that of 'locking' it against backward turning—hence the castellated nut.

But, as is only too well known by engineers, even with nuts positively so locked against turning on the threads, such assemblies do, in fact, become loose. Research has proved that the mere locking of the nut to prevent backward turning is *not* the answer to bolt tightness; the idea that a nut becomes loose initially from vibration or shock because it turns backwards on its thread is erroneous.

The initial looseness of a nut or bolt is due to one or more of these causes; lapping or wearing down to a closer bearing of the contacting surfaces; the break down of paint, scale etc. on the contacting surfaces; the release of the tension in the bolt assembly by gradual stretching or "creep".

Only so long as the stress on the bolt remains near to that set up by the original tightening will the bolted assembly remain tight. When, by reason of any of the causes enumerated above the stress or pressure falls below a certain point, then the assembly begins to be loose and only then may the point is not therefore to restrain the nut from turning backward, but to prevent the *pressure* between the parts of the assembly from diminishing. The readiest and most satisfactory way of doing this is a compressed spring under the nut—i. e. a helical spring lockwasher which retains it compensating compression force far beyond the point of initial or incipient looseness.

The art of successfully making a spring lockwasher is therefore to ensure that this 'springiness' or compressive force is present to a high degree in the washer, and that it is retained throughout its life. Great attention is therefore given by Toledo Woodhead

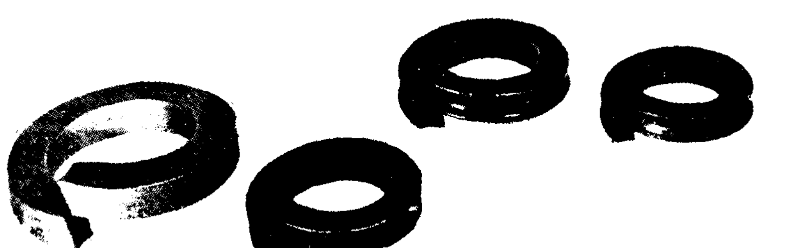


Fig. I A. General designs of spring washers for railway trackwork.

Fig. I B. Special designs showing latest types of single and double coil spring washers to meet all types of traffic conditions, exhibiting high reactive resiliency.

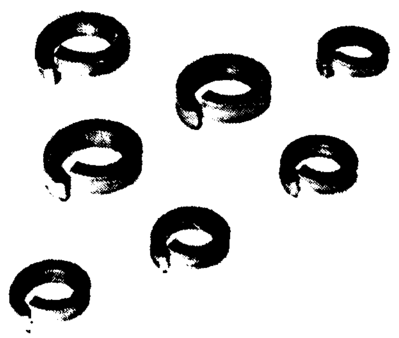


Fig. I C. General designs of spring washer suitable to mechanical work, locomotives rolling stock.

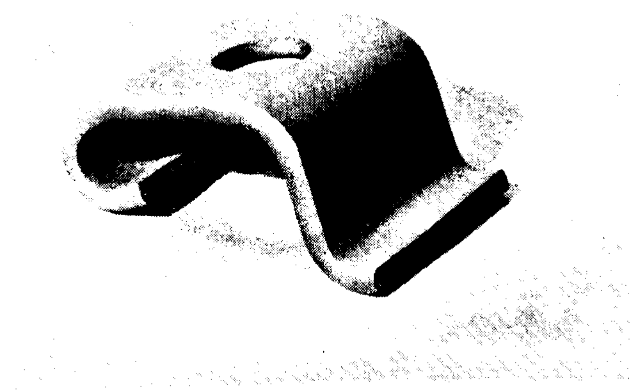


Fig. 2

Springs Ltd. to the selection of special steels to the required analysis, and to seeing that they are processed to the correct physical condition before manufacture of the washers commences.

During manufacture, constant tests are applied to ensure that the required 'springiness' is fully developed and that the lockwasher is in the correct condition of heat treatment and 'temper' for a too hard washer will fracture and a too soft one will fail to maintain the compressive strength on which its action depends.

A proportion of every batch of finished washers are subjected to severe temper tests (including a 36 hour clamping test in the case of plated washers) also twist and toughness tests under which the washers must show no sign of fracture.

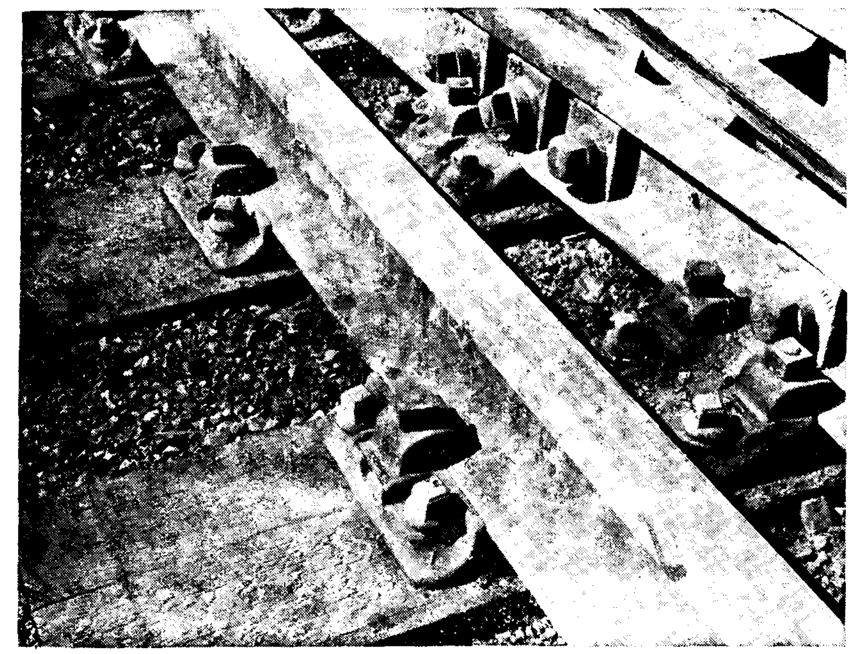
It will be noticed on the spring washer photograph that this includes the latest type of railway double coil spring washers, designed for the necessary reactive pressure to meet not only all types of traffic conditions, but also to provide reactive resiliency to prevent frozen joint conditions. The special single coil spring washer is most suitable for track application where a single coil spring washer is desired, but where a strong compression must be maintained and automatic prevention from wear without scoring the nut and bolted surfaces.

RAIL FASTENINGS—SPRING CLIPS

The Company also manufacture spring clip fastenings for use with flat bottom rails, having special application to the securing of rails at points and crossings.

One type of clip (Fig. 2) was developed by British Railways (to whom we are indebted for permission to reproduce photographs of the clip in use). The clip is made from spring steel of a suitable for specification. The projecting portion or tongue of the clip to the right of the illustration bears upon the chair; a recess or recesses in the chair are provided to house this tongue. The rounded or doubled-over portion bears on the flange of the rail and because of its shape will seat evenly

Fig. 3. Rail Clips at an important Junction of British Railways system.
(Photo: Courtesy of British Railways)



Left: Fig. 4. Close up view of rail clips in use at crossing.

thereon. Tightening is applied through the nut and bolt projecting through the hole in the centre of the clip, and the result is a spring-fastening, giving an elastic pressure exerting a consistent force on the base of the rail. By reason of its design, this type of spring clip is not only suited to securing rails at points and crossings, but also on main lines where extra rigidity is required, and where the usual type of rail fastenings, such as spikes, cannot be used.

Figs. 3 and 4—The spring clip rail fastening in use at an important junction on British Railways system; close-up of the spring fastening.

" Quality Control in Railway Workshops "

By Shri Jagjit Singh,

Joint Director, Efficiency Bureau Railway Board, New Delhi.

THE history of Western machine civilisation during the past three centuries may be divided into three successive but overlapping and inter-penetrating phases. The first phase began with the invention of the steam engine which ushered in an era of capitalism with its dark Satanic mills. By the close of the 19th century, however, two new sources of power came in sight, namely, electricity and the internal combustion engine. They gave rise to the second phase. This phase lasted till about the advent of the Second World War. By the time this war ended, it became clear that a new and vastly profounder technological revolution was under way bringing in its wake the third phase of the development of Western machine civilisation. This newer industrial revolution is basing itself on three major technological innovations, all of which took place during the forties of the present century though a good deal of preparatory work had to be done earlier before they could emerge in their present form. They are:

(i) Atomic Energy,

(ii) Cybernetics, and

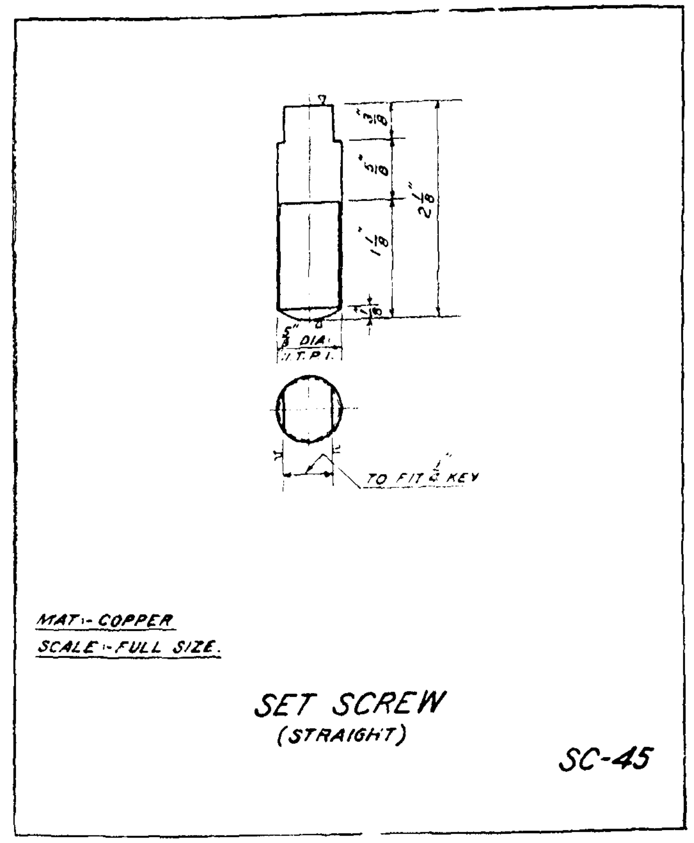
(iii) Quality Control

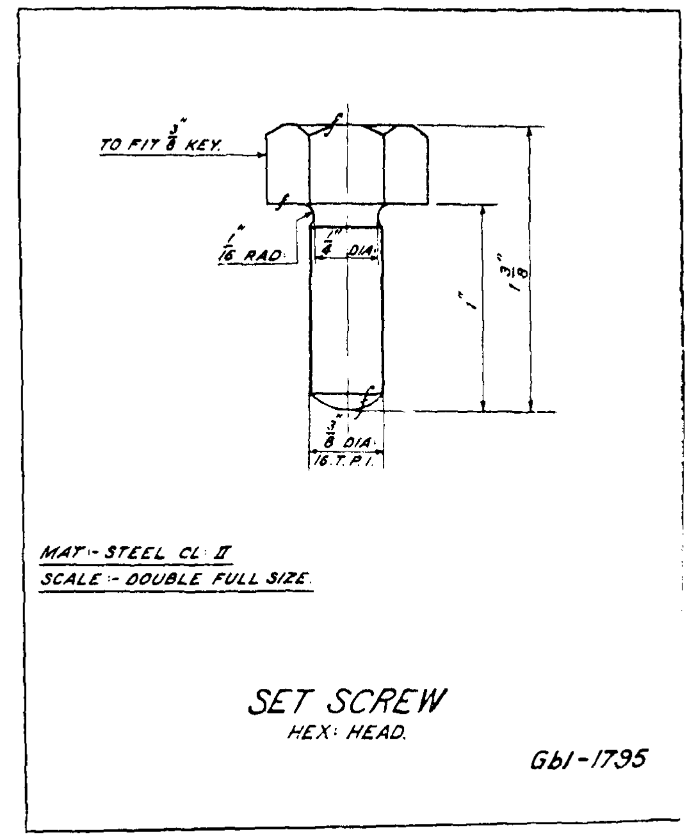
We all know how the vast reservoirs of energy locked up within the atom, can now be tapped, if only for purposes of war and destruction. Cybernetics as such is not so well known but it simply means the automatisation or robotisation of industry. It is the complement of the earlier industrial revolution of the 18th century in so far as it bids fair to devalue brain in much the same way as the former devalued brawn. I will not discuss these two any further here. I mention them because they along with Quality Control form the complex ideological basis of the third and latest phase of the evolution of machine civilisation.

The main characteristic of this latest phase is the mass production of goods. Now mass production of goods implies interchangeability of parts. This means that the measurements of each piece must be identical within certain permitted limits of error called tolerances. But due to tool wear and other factors a machine originally set to produce accurate pieces eventually begins to produce pieces whose errors exceed the tolerances. All such pieces have then to be rejected as scrap. The old method was simply to inspect occasional samples and to reset the machine when these were found to be outside the required limits. But in between such occasional and haphazard settings many pieces were produced with too great errors so that they had to be scrapped or reworked. Quality Control uses the science of statistics to avoid this waste. From statistical examination of the production capacities it is able to calculate a new set of inner limits narrower than the prescribed tolerances. When the errors on more than a certain number of samples exceed these, the pieces are still sufficiently good for use, but it is a warning to the producer that the machine is liable soon to become so inaccurate as to produce scrap. It is therefore stopped and adjusted immediately and wastage of time and material (which very often occurs elsewhere) is avoided.

This in plain language is the rationale and technique of Quality Control. But such a bare description, though good enough for a general understanding of the idea underlying Quality Control, does not suffice if one wishes to apply it in one's daily practice. It is, therefore, necessary to embellish it a bit with a little technical rhetoric.

Now the technical meaning of Quality Control like so many other scientific terms such as force, energy, work, horse power, etc. is merely a refinement of its everyday meaning. The Oxford dictionary lists the following meanings of the word quality; degree of excellence, relative nature or kind or character, general excellence, etc. Accordingly in ordinary parlance when we say that so and so *has quality we mean that it* has a degree of excellence of which there cannot be too much. In the technical sense it has a wider, if more neutral, connotation. Here it may mean something like a size which is required to be neither more nor less than a certain value or it may even mean something that is undesirable such as the appearance of a flow or a defect. It may be described qualitatively as something good or bad, acceptable or rejectable as is the case when we sort out a batch of products by means of a " go " " no-go " gauge, or alternatively it may be measured numerically as, for instance, in the case of a particular impurity in a chemical compound, the tensile strength of a sheet of metal, the life of an incandescent lamp, the resistance of an electric coil, the diameter of a ball bearing, or the thread of a screw, etc. How the quality or attribute of an article is to be expressed or measured is a technical problem which must be solved first before the Quality Control statistician can make any useful contribution. He comes in the field because when





articles are mass produced it is impossible to deal with individuals. To explain his technique, let us consider some concrete production process such as is actually employed in the Jamalpur Workshop as, for instance, the production of set screws type F4, which to use Stores Branch nomenclature goes under the number SC-45. One quality of such screws is described by the measure of its diameter which ideally should be $\frac{5}{8}$" or .625 in decimal notation. *Since it is not possible to* produce screws with diameters exactly equal to .625 the drawing office also prescribes tolerance limits which in this case are 0 and − .009.

Table I is a record of the measures of 100 such screws produced in Jamalpur Workshop recently. A table of 100 individual measures may look large but 100 is only a small number. In Jamalpur Workshop itself the production exceeds 100 per shift. But this Workshop is quite a long way off the mass production workshops of the modern machine world. Their output runs into millions or even more. Consequently when we have an array of measures of a large number of mass produced products, our first problem is to find a way of summarising the mass of figures presented to us. In order not to miss the wood for the trees, it is necessary to replace a long array of figures such as those shown in Table I by a few selected figures preferably by a single one. How shall we proceed so as to discover a single figure that could in some way be taken as a representative of the entire array? There are several ways of doing this but I shall mention here only one, viz. that of replacing the array by its average or arithmetic mean. As is well known, we calculate it by merely adding all the figures in the array and dividing the sum by the number of figures so added. In the case of the figures given in Table I our arithmetic mean or average is .630. But it will be appreciated that a single representative figure such as the average can only give a somewhat oversimplified picture of the state of affairs revealed by the entire array of figures. If we want a deeper grasp of our facts we have to relax the restriction we imposed at the outset, viz. to make do with a single representative figure. Suppose then we were permitted to summarise an array of figures by two or more figures instead of only one. How shall we proceed? In the first place we may choose the average as one of the two or three figures permitted us in preparing our summary. How shall we select the other figures? That depends on whether we want to have only one or two additional figures. If we want our summary to consist of two additional figures, we can select the maximum and minimum values from our array of figures in addition to the average. We could thus summarise the array of figures in Table I by three numbers:

Average:	.630
Minimum:	.622
Maximum:	.635

But if we wanted our summary to contain only two figures, we could take the difference between the maximum and minimum, viz., .635 − .622 = .013 as a measure of the range within which the measures of Table I vary. Our summary then is:—

Average:	.630
Range:	.013

For technical reasons into which we need not go now, statisticians have not taken kindly to the idea of using range, that is, the difference between the maximum and minimum as a measure of the variance or spread of the given array of figures. They prefer to use another measure called the standard deviation for this purpose. The idea of standard deviation may most simply be explained as follows:

Let us take the figures of the diameters of the screws shown in Table I as an illustration. To minimise the computational labour we may work with the first ten figures of this table though the method will naturally apply to as many of the 100 figures in the table as we may care to choose. The mean or average diameter of the first ten screws is .6297. If we take the deviation or difference of the individual figures from our mean, we have another set of figures equal in number to our original set. These ten deviations are obtained by subtracting the mean from each of the 10 items in succession. They are:

(.632 − .6297), (.0023)	(.631 − .6297), (.0013)	(.624 − .6297), (− .0057)
(.633 − .6297), (.0033)	(.629 − .6297), (− .0007)	(.628 − .6297), (− .0017)
(.631 − .6297), (.0013)	(.631 − .6297), (.0013)	(.628 − .6297), (− .0017)
(.630 − .6297) (.0003)		

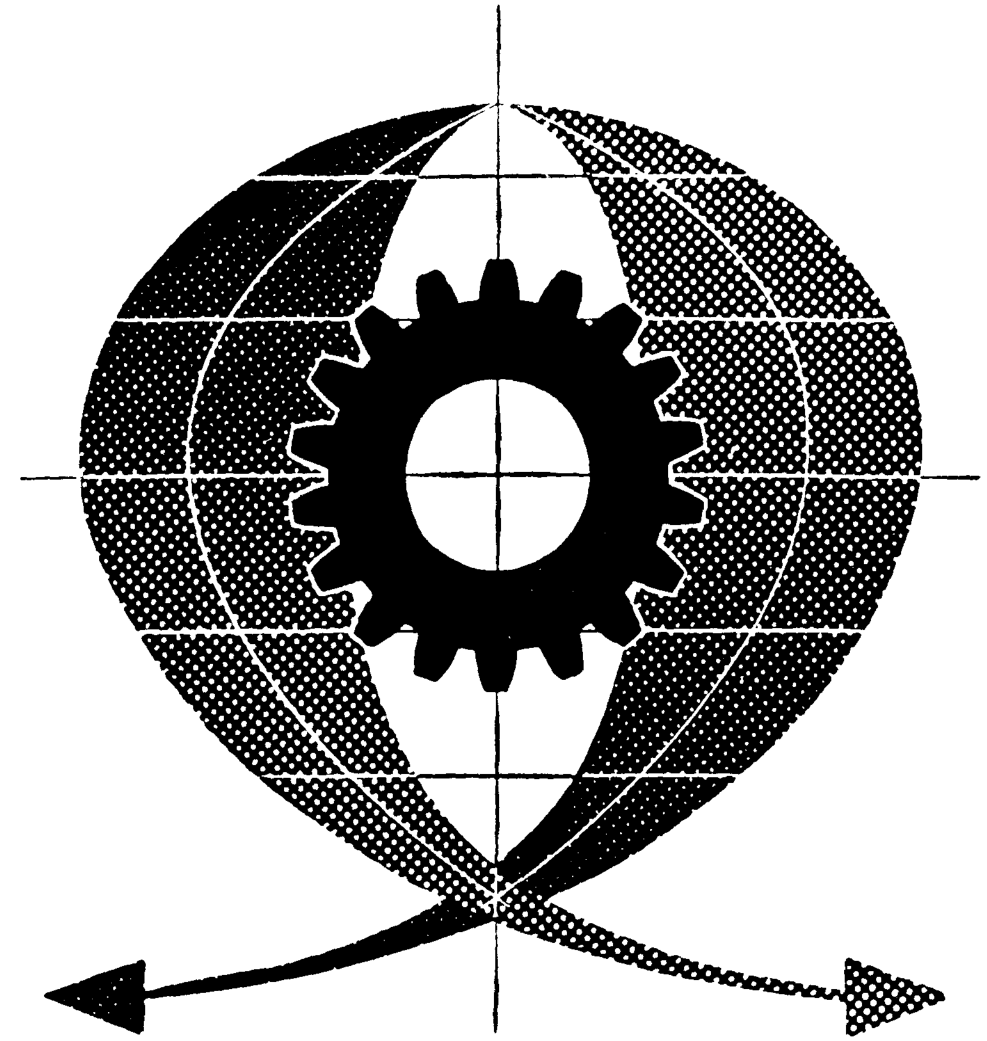
We could replace this new set, the set of deviations (or differences from the mean), by a single figure as a representative of the entire set. This latter figure could then be taken as a measure of the magnitude of the variation or "spread" of the original figures from their arithmetic mean. How shall we replace our set of deviations or differences from the average by means of a single figure? If we took the average of these differences (each difference with its appropriate sign), we should get zero as the average of these differences as a glance at the figures shows. In fact, such complete cancellation of positive and negative deviations noticed in this particular case is the rule in every case on account of the very nature of the arithmetic average. It would therefore seem that it is no use taking the average of these differences or deviations as we shall always get one and the same result viz. zero. To avoid this difficulty we could ignore the minus sign of the differences and strike their arithmetic average *as if* all the differences were positive. We could thus replace the array of differences by means of this average of the differences all of them being regarded as positive. This would give us a measure of the variance or "spread" of our original array of figures. For instance, the average value of the deviations quoted above regardless of their signs would be .0196/10 = .00196 or .002. This figure viz., .002 may be taken as representative of the set of individual deviations from the mean and therefore as a measure of the "spread" of screw diameters round the mean. It is known as the mean deviation.

However, tampering with the signs of deviations brings its own nemesis in the long run. It makes this measure of variance or "spread" mathematically intractable. Statisticians therefore do not favour this idea. They prefer to solve the difficulty in another way. If some of the differences are positive and others negative, and if the sum of the positive differences always cancels out that of the negative differences, we could make them all positive by squaring the differences. We could now deal with squares of differences which are all positive. We could sum up these squares. Dividing this sum by the number of differences added we would get the average of these squared differences. We now take the square root of this average to come back to the same level of figures as the original. This is known as the *standard deviation* and gives a measure of the "spread" of the given set of figures round the average. Using the ten figures of screws diameters quoted above as our illustration, we have our array of differences or deviations from the arithmetic average as shown below:—

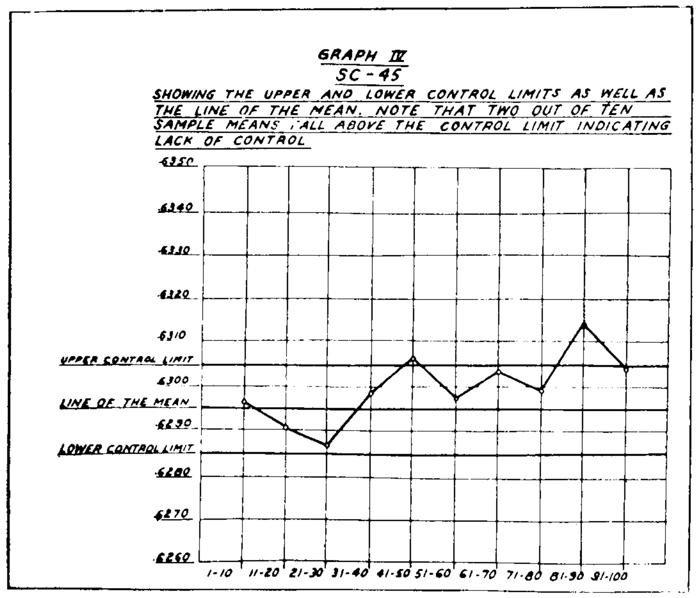
+ .0023, + .0013, − .0057, + .0033, − .0007, − .0017, + .0013, + .0013, − .0017, + .0003.

We may readily verify that the average of the squares of these ten differences is 000006010. Its square root is .00245 or .0025 which is thus the value of our standard deviation.

Now you have every right to demand as to why statisticians prefer to use this roundabout method of calculating the standard deviation as a measure of the "spread" of the given array of figures to the simple



without the additional supervision conforms to the ideal all that we need is to examine the means of samples of the same size picked up at random from time to time. The sample size is arbitrary and we may fix it to suit our convenience. Suppose in the case of set screws we decide to work with samples of ten. Then we first draw the control chart like this. On a graph paper we draw a horizontal line to denote the ideal mean of the process which as we saw was .630. Parallel to this horizontal line we draw two central lines at a distance $3\frac{\sigma}{\sqrt{n}}$ above and below it, where $\frac{\sigma}{\sqrt{n}}$ is the standard deviation of the items under ideal conditions and n is the sample size. In the particular case cited above, σ is .00165 and n is 10 so that the control lines are located. .00148 above and below the central line as shown in Graph IV. On this control chart then we go on plotting the means of samples of ten readings taken from time to time. If the sample means remain mostly within the control limits, we may be reasonably certain that the process is under control producing variation of the same pattern as we obtain when it is conducted under ideal conditions. The rationale of the technique is that if individuals in any large lot have any standard deviation, then the standard deviation of the sample means picked up from the lot will be considerably less than that of the individuals. For the process of averaging will reduce the variability. In most cases, it can be shown that the standard deviation of the means of samples of size n is simply $\frac{\sigma}{\sqrt{n}}$. Since 99% of the items lie within the range a ± 3s, it follows that 99% of the sample means will lie within the control limits drawn in the a fore-mentioned manner. Consequently if our control chart shows more than 1% of the points plotted falling outside the control limits this is an announcement that assignable causes of variation have crept in and we must locate the source of trouble. In the case of set screws of Table I, we easily see from Graph IV that the process was out of control as two out of ten points fall outside the control lines.



Although Quality Control was originally employed to reduce production costs by preventing waste, eliminating re-work and decreasing the amount of necessary inspection, this is not its only use. Spectacular as have been the savings on inspection costs effected by its use in some cases there may not be any. This does not mean that it has no other use if the potentialities of saving inspection costs are limited or do not exist at all. Quite the contrary. For it can often be used to influence decisions regarding specification and production. For example, the variability pattern of a given process may in some cases prove quite suitable and the tolerance limits specified by the drawing office may be over-strict. It may thus be used to revise the specified tolerances and thus save a large proportion of unnecessary rejects or alternatively unnecessary expenditure on modifying the process to produce the specified tolerances.

Other incidental uses of Quality Control are:

(i) Improvement of inspection standards as it entails the preparation of definite instructions for each inspection procedure;

(ii) Establishment of an effective inspection process where none exists before;

(iii) Providing valuable hints regarding the causes of trouble and possible remedies when control charts hows assignable causes. Sometimes the pattern of points on the charts gives some clue to the cause of trouble. Tippette, in his book Technological Applications of Statistics, mentions a girl in charge of control charts in a workshop who, though not an engineer, had developed an almost uncanny flair for telling the technical people what was wrong from a mere examination of the chart.

These considerations show that we should not be deterred from employing the technique of Quality Control in railway workshops merely because the number of items produced is in many cases not large enough. For instance, in the case of SC-45 screws mentioned above method of calculating the mean deviation. The reason is that the standard deviation enables us to state precisely what proportion of figures would lie within any stated range. In most cases we find that we make very little error if we assume that 50 % of the figures of our array lie within the range a — ⅔s and a + ⅔s, where a is the average and s the standard deviation of the array. Similarly 95 % of the figures lie within the range a — 2s and a + 2s and 99 % within a — 3s and a + 3s. This is a rough rule, of course, but it is one which is found to work well enough in practice. In the case of our array of ten figures of diameters considered above we found a = .630 correct to the third decimal and s = .0025, the range a ± ⅔s, i. e., (.6283, .6317) contains five items of the array. This works to 50 % as postulated by the rule. Likewise, the range a ± 2s viz. (.625, .635) contains nine out of ten items of the array. This works to 90 % instead of 95 % postulated by the rule. Finally the range (.6225, .6375) includes all the ten items instead of 99 % postulated by the rule.

In fact, a knowledge of the mean 'a' and standard deviation 's' of any given array would enable us to state in most cases at least approximately the percentage of figures lying in any stated range a ± ns. If we give to 'n' different values like n = ⅔, 1, 1.5, 2 etc., we get different ranges. Tables exist which enable us to state the percentage of figures of our array lying in the range a ± ns for various values of 'n'.

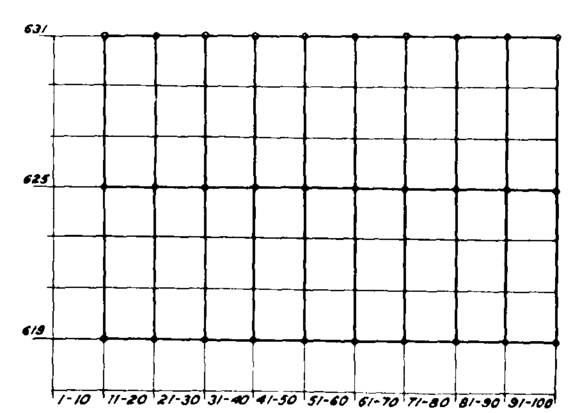
Now if one understands the meaning of the two basic statistical concepts described above, viz. the mean and standard deviation, it will not be difficult to understand the rationale underlying the methods of Quality Control.

As already mentioned these methods have been developed primarily to meet the needs of the mass production of discrete articles but they can be and have been adapted to meet other needs. The ideal of mass production is to know and maintain at appropriate levels all the factors that determine quality so that all the articles produced have the required specification. According to this ideal, for example, the Works Manager of the shop producing SC-45 screws considered above, endeavours to so arrange production as to ensure the diameter to be the standard size which in this case is .625. In practice, however, it is either impossible, impracticable or uneconomic to control all the conditions precisely. Raw materials, particularly those of biological origin such as wood, for example or even cast or wrought iron and steel cannot be made uniform. Processes have to be controlled by human operators and it is impracticable to exercise supervision close enough to eliminate the effects of the human factor entirely. Machines and tools wear and it is uneconomic to scrap them at the first appearance of a slight wear. All these sources of variation are natural to the process and since we have to put up with them we may describe the resulting variation in quality as allowable. Sometimes, on these inevitable if allowable variations are superimposed those that occur when things go wrong or when there is some change in conditions that can be identified and controlled. These variations may be called preventible variations. The aim of the methods of quality Control is to separate *allowable* from *preventible* variations so that we may know when causes of preventible variations which are called assignable causes are in operation.

The distinction between the two kinds of variations may be further illustrated by means of an example. Consider, for example, the production of the SC-45 screws mentioned above. If we examine a lot of, say, 10 such screws produced in succession, we may replace the group of 10 such readings by a summarised picture given by only two numbers, viz. their mean and standard deviation. Suppose their mean is .625" and standard deviation .002. Consequently the set of 10 readings may be replaced by the range .625 − 3 (.002), .625 + 3 (.002), or (.619", .631"). Graphically this may be represented by a vertical line as shown in Graph I. In

GRAPH-I.

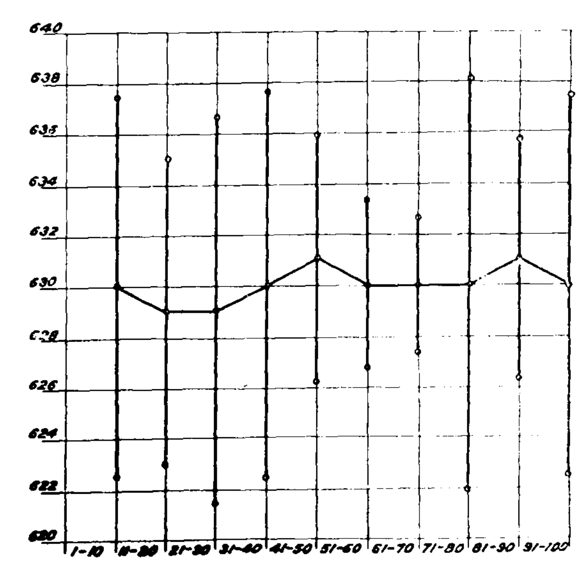
MEAN AND STANDARD DEVIATION OF HYPOTHETICAL SAMPLES OF 10 SET SCREWS EACH. NOTE THAT THE MEAN & STANDARD DEVIATION OF EACH SET REMAINS THE SAME SHOWING THAT BOTH ARE UNDER CONTROL.



the same way we may represent subsequent lots of ten readings by vertical lines. It may happen that vertical lines representing the successive lots are as shown in Graph I. Here, as will be observed, the lot means and their standard deviations are the same in every case though the individual readings in each lot are different from those in the others. This shows that the basic pattern of variation of the successive lots remains the same. Consequently we may say that only allowable causes of variation are at work and both the mean and spread are under control. But such an ideal state of affairs does not usually obtain. Consider for example, the ten sets of 10 readings each as actually observed. They are given in Table I. If we represent graphically these readings in the manner described above, the state of affairs is like that shown in Graph II. It will be observed that here both the mean and variability of the sets of readings are out of control. Sometime it happens that one of the two is under control while the other is out of control. As an instance of this type of lack of control, consider the measurements of another type of set screws viz. Gb,-175 shown in Table II. If we represent graphically these readings, the result is Graph III. It will be seen that except for the last lot of

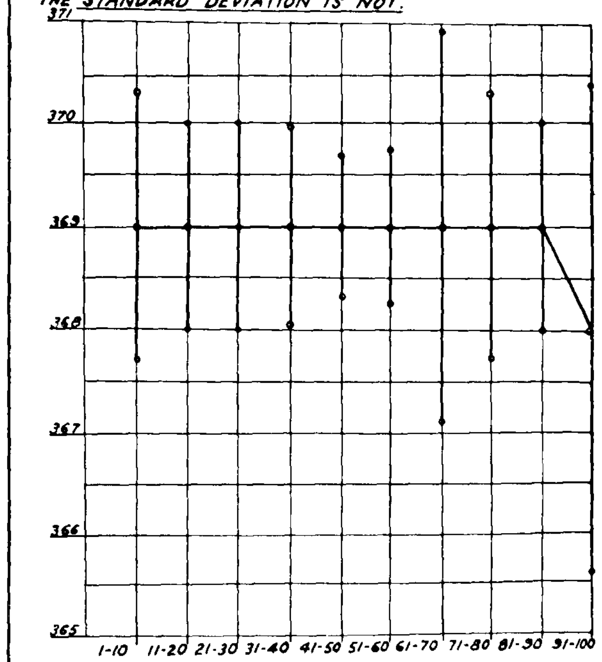
GRAPH - II
SC-45

MEAN AND STANDARD DEVIATION OF ACTUAL SAMPLES OF 10 SET SCREWS EACH. NOTE THAT BOTH THE MEAN STANDARD DEVIATION OF THE SETS ARE OUT OF CONTROL.



GRAPH III
Gbl - 1795

MEAN AND STANDARD DEVIATION OF SAMPLES OF 10 SET SCREWS Gbl-1795 EACH. NOTE THAT WHILE THE MEAN OF ALL SAMPLES EXCEPT THE LAST IS UNDER CONTROL THE STANDARD DEVIATION IS NOT.



ten readings, the lot means were under control though not their variability.

Now how are we to discover in actual practice as to whether any given production process is under control or not? There are various ways of doing this, but for want of space I shall describe here only one of these. We may, for example, conduct the operation under close supervision so as to secure its actual working as near the ideal as the process is capable of. We may then measure the quality of the products so produced. The data so collected will then enable us to calculate the mean and standard deviation of the products when produced under such ideal conditions. To fix ideas let us suppose that the measures of twenty SC—45 screws produced under such ideal conditions are*

.631, .629, .631, .630, .630, .630, .631, .630, .635, .629, .630, .631, .631, .630, .630, .630, .627, .630, .629, .629.

This set yields .630 as the mean with .00165 as the standard deviation. Now suppose we withdraw the intensive supervision and let the process continue under ordinary conditions. To ensure that the normal process

*I should like to add that the measures given here are those actually obtained *without* any such close supervision. That is why they do not conform to the specified standard .625 with tolerances 0 and —·009. These figures have been taken merely to illustrate how one may obtain the inner control limits narrower than the tolerance limits.

lack of quality control resulted in the production of only 7% of the screws within the specified tolerance. The result of this would be that when the screws are fitted into the corresponding nuts, the fit would be very much tighter than it should be. This would have two undesirable effects. First it would mean greater effort on the part of the fitter to fit the screws and thus reduce his output to some extent. Second, such overtight fits are liable to set up unhealthy strains in materials which lead to avoidable fatigue and failure.

Of course, there are various other fields of our workshops activity where Quality Control may be employed more usefully than in others. Here one's technical knowledge of the workshop practices alone can be a safe guide.

TABLE—I

STATEMENT FOR SC-45

No.	*Size.*	*No.*	*Size.*	*No.*	*Size.*
1.	0.632	35.	0.631	69.	0.630
2.	0.631	36.	0.630	70.	0.632
3.	0.624	37.	0.623	71.	0.632
4.	0.633	38.	0.630	72.	0.631
5.	0.629	39.	0.630	73.	0.631
6.	0.628	40.	0.631	74.	0.630
7.	0.631	41.	0.631	75.	0.631
8.	0.631	42.	0.629	76.	0.630
9.	0.6275	43.	0.631	77.	0.631
10.	0.630	44.	0.630	78.	0.631
11.	0.6295	45.	0.630	79.	0.622
12.	0.6295	46.	0.630	80.	0.630
13.	0.629	47.	0.631	81.	0.631
14.	0.631	48.	0.630	82.	0.629
15.	0.624	49.	0.635	83.	0.634
16.	0.630	50.	0.629	84.	0.632
17.	0.628	51.	0.630	85.	0.632
18.	0.632	52.	0.631	86.	0.630
19.	0.629	53.	0.631	87.	0.629
20.	0.6285	54.	0.630	88.	0.632
21.	0.625	55.	0.630	89.	0.632
22.	0.628	56.	0.630	90.	0.633
23.	0.629	57.	0.627	91.	0.633
24.	0.625	58.	0.630	92.	0.623
25.	0.631	59.	0.629	93.	0.632
26.	0.631	60.	0.629	94.	0.632
27.	0.625	61.	0.629	95.	0.630
28.	0.630	62.	0.631	96.	0.630
29.	0.631	63.	0.631	97.	0.630
30.	0.631	64.	0.639	98.	0.632
31.	0.632	65.	0.630	99.	0.632
32.	0.631	66.	0.631	100.	0.630
33.	0.632	67.	0.630		
34.	0.628	68.	0.630		

TABLE—II

STATEMENT FOR Gbl-1795

No.	*Size.*	*No.*	*Size.*	*No.*	*Size.*
1.	0.369	34.	0.368	67.	0.369
2.	0.369	35.	0.369	68.	0.369
3.	0.369	36.	0.369	69.	0.369
4.	0.368	37.	0.3685	70.	0.3695
5.	0.369	38.	0.3685	71.	0.369
6.	0.369	39.	0.3685	72.	0.369
7.	0.3695	40.	0.369	73.	0.369
8.	0.3695	41.	0.369	74.	0.369
9.	0.3695	42.	0.369	75.	0.368
10.	0.369	43.	0.3685	76.	0.3685
11.	0.368	44.	0.369	77.	0.3695
12.	0.369	45.	0.369	78.	0.3695
13.	0.369	46.	0.369	79.	0.3685
14.	0.369	47.	0.369	80.	0.369
15.	0.3685	48.	0.3685	81.	0.369
16.	0.369	49.	0.3685	82.	0.369
17.	0.369	50.	0.369	83.	0.3685
18.	0.3685	51.	0.3685	84.	0.369
19.	0.3685	52.	0.3685	85.	0.3685
20.	0.369	53.	0.369	86.	0.3685
21.	0.369	54.	0.369	87.	0.3685
22.	0.368	55.	0.3685	88.	0.368
23.	0.369	56.	0.3685	89.	0.369
24.	0.369	57.	0.3685	90.	0.369
25.	0.369	58.	0.369	91.	0.369
26.	0.3685	59.	0.369	92.	0.3695
27.	0.3685	60.	0.369	93.	0.3685
28.	0.3685	61.	0.3685	94.	0.369
29.	0.369	62.	0.367	95.	0.367
30.	0.369	63.	0.369	96.	0.3685
31.	0.3685	64.	0.369	97.	0.369
32.	0.369	65.	0.3685	98.	0.368
33.	0.3685	66.	0.3685	99.	0.367
				100.	0.3685

Cheaper Electrification for British Railways

THE British Transport Commission have announced the adoption of 25,000 volts, 50-cycle A. C. system for main line electrification. Railway electrification in Britain will be carried out more cheaply, more simply and probably more quickly, as a result of this decision, subject to the approval of the Minister of Transport. The British Transport Commission, have decided to adopt as standard a system embodying the latest technical progress, which takes current direct from the national grid.

This system employs 25,000 volts, 50-cycles alternating current, with overhead wire conduction. The 50-cycle system has already proved successful on sections of the French Railways, and on a British Railways experimental is tallation introduced in 1952 between Lancaster, Morecambe and Heysham.

It will now be used on 1,210 of the 1,460 route miles of British Railways, the electrification of which, as already announced, will be carried out under the Modernisation Plan at a cost of about £185 millions, and on all subsequent electrification schemes other than in the Eastern and Central Sections of the Southern Region and on London Transport. The lines involved in this part of the plan comprises :-

(a) *Electrification of Main Trunk Routes :* (820 route miles)

(i) *London Midland Region Main Lines*

Euston to Birmingham, Crewe, Liverpool and Manchester.

(ii) *Eastern & North Eastern Regions Main Lines*

King's Cross to Doncaster, Leeds and (possibly) York.

(iii) *Eastern Region Main Line (in extension of existing electrification)*

Liverpool Street to Ipswich, including Clacton, Harwich and Felixstowe branches.

(b) *Suburban Electrification :* (390 route miles)

(i) London, Tilbury & Southend line.

(ii) Liverpool Street to Enfield and Chingford.

(iii) Liverpool Street to Hertford and Bishop's Stortford.

(iv) King's Cross and Moorgate to Hitchen, and Letchworth including the Hertford loop.

(v) Glasgow suburban lines.

There are 1,796 miles of track in the Southern Region which are already electrified on the 660 volts D. C. system with third rail conduction. To alter this would be very costly and would seriously delay extension of the electrification in this region; the 250 miles of extensions in the Southern Region which are included in the initial 1,460 miles under the Modernisation Plan will therefore be carried out on the existing third rail system.

ADVANTAGES OF A. C. OVER D. C.

Following are the principal advantages of the A. C. overhead system as compared with the 1,500 volts direct current overhead system latterly adopted in British railway electrification :—

Power Supply

Costs of power supply equipment, substations, and feeder cables, also power consumed and of maintenance, will all be less ; supply will be more reliable.

Overhead Equipment

Since a lighter conductor wire can be used, less copper is required.

Overhead structures are lighter, cheaper, and use less steel ; they will be easier to erect.

Although alterations to tunnels and bridges (to give the greater clearance needed for the overhead wire carrying high voltage) are more difficult and costly, this will be more than counter-balanced by the overall saving.

Motive Power

Better adhesion, enabling lighter locomotives to be used, and easier control. Fewer locomotives needed.

No power will be wasted in main resistances for speed control.

Electric heating and lighting can be supplied to trains more cheaply and economically.

Despite the much higher voltage of the A. C. supply, the safety of the public and of railway staff will be in no way diminished. Indeed, in some respects the A. C. system is safer.

SUBSTANTIAL ECONOMIES

As a result of the experience already gained, and of a special comparative survey recently carried out of the heavily-trafficked main lines of the London Midland Region from Euston to Manchester and Liverpool (a summary of this survey is given later) the British Transport Commission are satisfied that the A. C. system offers substantial economies both in first cost and in annual costs of operation. They consider that the system will permit the electrification in the future of some secondary lines on which electrification by the D. C. method could not be financially justified. Moreover, they consider that apart from the technical advantages which are immediately available, the A. C. system offers greater potential for development in design and technique than is the case with other systems.

CHANGE OF POLICY

The adoption of the A.C. system marks a fundamental change in the application of electricity to rail traction. A B. T. C. technical committee recommended in 1951 that future electrification should be at 1,500 volts D. C. Since that time, however, rapid technical developments have made it possible to apply the 50-cycle single-phase system to railway purposes, and so to obtain the benefits of lower cost and higher efficiency associated with A. C. while retaining the advantages of the robust D. C. series traction motor.

The Commission's decision to adopt the new system has the full concurrence of the Central Electricity Authority and is supported by the electrical manufacturing industry.

SUMMARY OF SPECIAL SURVEY

The special survey of the Euston-Manchester-Liverpool route for the purpose of comparing the respective costs of A. C. and D. C. electrification gave the following results :—

FIGURES IN MILLION POUNDS STERLING

	25kV. A.C.	1,5000V. D.C.	Difference in favour of A.C.
Power supply and overhead system (including cost of providing clearances).	29.3	38.6	9.3
Motive power, including electric trains, but excluding hauled stock.	48.6	46.3	—2.3
Signalling	25.0	24.5	—0.5
Depots	2.7	2.7	—
Train heating and lighting	6.1	7.1	1.0
Contingencies	6.1	4.4	—1.7
TOTAL	£117.8	£123.6	£5.8

Omitting the cost of signalling and depots, which is about the same for either system, the direct cost of A. C. electrification is 93% of that by D. C.

A reduction of £1 million a year in annual costs is also expected to accrue from the use of the A. C. on this very busy line, on which it is desired to start work as quickly as circumstances permit. The electrification of the section between Manchester and Crewe will be carried out as the first stage as soon as possible.

Noteworthy points of detail from the survey of the Euston-Manchester-Liverpool line, are that the A. C. electrification will require 12 substations instead of 70; 68% less copper for conductor wires, and 17% less steel for conduction equipment. Instead of 250 miles of 33kV feeder cable to take the current from the Central Electricity Authority, less than 17 miles will be necessary, and the aggregate capacity of the transformers required can be reduced by one-third. Sixty fewer locomotives will be needed.

POSITION OF EXISTING ELECTRIFIED LINES

The most important of the existing electrified lines which will be affected by the decision to adopt A. C. is that in the Eastern Region between Liverpool Street and Shenfield, now in course of extension to Southend and Chelmsford on the 1,500 volts D. C. system. Although certain problems of clearances are involved, this group of lines will be converted to the new A. C. system so as to conform with the forthcoming extension into East Anglia. In fact, the total cost of carrying out the Eastern Region electrification in East Anglia on A. C., including the conversion of the Shenfield line and its extensions, will be less than if the 1,500 volts system were used throughout.

The Liverpool-Southport, Wirral, Tyneside, and Euston-Watford lines, which are electrified on the 630/660 volts third or fourth rail system, are more or less self-contained and it is not proposed to alter them; similarly, the Manchester-Altrincham line (1,500 volts D. C. overhead) need not be altered yet. The Manchester-Sheffield-Wath electrification (also 1,500 volts D. C. overhead) is not scheduled for extension under the Modernisation Plan.

The Manchester-Bury electrical equipment (1,200 volts D. C. third rail) will have to be renewed shortly and consideration is being given to conversion to A. C.

* * *

RAILWAY MODERNISATION PLAN—VACUUM BRAKES FOR FREIGHT ROLLING-STOCK

The British Transport Commission announce today that a decision has been reached on the type of power brake to be fitted to British Railways freight rolling-stock under the £ 1,200 millions railway Modernisation Plan.

After extensive research and practical trials it has been decided to adopt as standard the vacuum type of continuous automatic brake at present in use on almost all B.R. passenger coaches hauled by locomotives, and on some 179,000 of the 1,126,000 railway freight wagons.

This decision will have far-reaching effects on both passenger and freight services in the future and will lead to the all-round speed-up of both types of traffic.

The decision to adopt the vacuum brake, which has a long and proved record of reliable service under British conditions, will mean that 30,000 merchandise wagons already authorised will continue to have the vacuum brake fitted, while immediate steps will be taken to equip as many as possible of the 100,000 mineral wagons on order.

Existing vehicles, and those which will be supplied under the present contracts without power brakes, will be fitted as equipment becomes available. Meanwhile British Railways are to intensify the development of the vacuum brake which should increase its efficiency.

ADVANTAGES OF CONTINUOUS BRAKES

The fitting of continuous brakes to all freight wagons is a major feature of the railway Modernisation Plan launched last year. Although the number of wagons fitted with the continuous brake has steadily increased, a large proportion of railway freight traffic is still carried in loose-coupled wagons fitted with hand-brakes only. The substitution, by new construction and by conversion, of a fully-braked fleet of wagons, will not only enable freight trains to run much faster at maximum speeds of up to 60 m.p.h.; it will raise the average speed of movement all over the railways; will obviate many delays to freight trains through their having to be shunted for faster trains to overtake them; will enable British Railways to offer better transit times for freight traffic; will improve punctuality, and will give greater safety in train movement. Moreover, the higher average speeds of traffic movement will lead to a reduction of about 2,000 locomotives, and in conjunction with other improvements, will enable the total wagon stock to be reduced to about 752,000 by 1974, while giving a much better service.

THE VACUUM BRAKE

With the vacuum type of brake, the brakes throughout the train (each vehicle being connected to the next by a continuous pipe) are released and kept off by exhausting the air from the brake system by means of equipment on the locomotive. The brake is applied by the admission of air to the brake-system, thus reducing or destroying the vacuum.

The brake operates on all vehicles connected together by the brake train-pipe; is under the direct control of the driver (with emergency control by the guard), and is applied in emergency by the pulling of the passenger communication card; should a train break in two, both portions are stopped by the automatic action of the brake.

OTHER IMPROVEMENTS

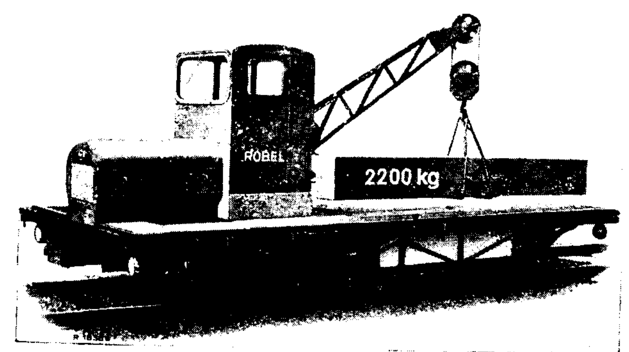
In the Modernisation Plan, the cost of fitting all goods wagons with the continuous brake was estimated at £75 millions. Trials have shown, however, the

(Continued on page 37)

Economy in Permanent Way Maintenance

(By a Special Correspondent)

THE considerable cost involved in the continuous maintenance of railway trucks, which is an important factor in the safety of rail transport, has induced the Federal German Railways to mechanise construction and maintenance work on permanent ways. Various large units are already in operation and have resulted important savings. Among others, a large number of railcars of the type illustrated below have been put into service and have proved to be most economical in use on maintenance work, ever since they were first introduced.



Ganger's Railcar Robel 11 with crane and lifted load, side walls removed.

These vehicles are used for the speedy transport of crews, constructional machinery and equipment, fuel, rails, sleepers and other materials to the site.

The railcars are powered by a robust, air-cooled Deutz diesel engine of 72 h.p., driving through a four-speed gearbox with forward and reverse drive. The brakes are generously dimensioned. The drive is transmitted to both axles, so that even under the worst weather conditions the railcar can take in its stride the steepest gradients encountered in railway practice. To protect the driver against bad weather, an enclosed cabin is provided.

Because of the economy in operation of this railcar and because of the considerable savings in time and labour which can be achieved through its use, several railway organisations outside Germany have now followed the example of the Federal German Railways and have purchased railcars of this type.

The illustration shows the railcar made by Robel & Co., of Munich, Germany, manufacturers of special equipment for the railways. The Robel railcar represents the latest product of many years of experience in this field.

(Continued from page 36)

need for wagons of freight trains to be close-coupled by screw-couplings (as on passenger trains) if the sustained high speeds which will be required of freight trains in the future are to be reliably maintained, while roller-bearings and improved brake-fittings will also require to be fitted, especially to high-capacity wagons. These improvements will involve an additional outlay, over the whole period of the Plan, of from £50 to £60 millions, which is equivalent to no more than one year's total financial betterment in respect of freight traffic, when the benefits of the Modernisation Plan are in full operation.

As summed up in the Modernisation Plan, "the adoption of continuous brakes" is one of the most important single steps forward that can be taken by British Railways in the near future to improve the standard of their service and it will be of material assistance in getting the best results from new forms of motive power.

Automatic Train Control on the German Federal Railways

By D. W. Chilian *

SOON after the 1st World War, the German Railway recognized the necessity of introducing a system of Automatic Train Control by which it should be possible to enforce a train moving on any line section to adhere strictly to the signals indicated to it for its safe passage along this section. This system should prevent the engine driver to pass any signal at 'danger' and enforce an automatic braking of the train in case he should not respond immediately to the signal.

The development of such a system which is commonly known as Automatic Train Control, was substantially pioneered in Germany by the firm of Siemens & Halske, and this system is also known on the Continent under the abbreviation INDUSI. The vital problem for such a system was a reliable transmission of controls from an apparatus on the track to the running train at speeds ranging from nearly zero up to the highest ones, being at this time 100 m.p.h. The system adopted was capable of a reliable transmission of multi-aspect signal controls by non-mechanical means.

The German State Railway at this time selected a 3-frequency system, thus allowing 3 different controls to be transmitted simultaneously.

From 1935 up to 1940 a total number of 1000 engines, mostly steam ones, have been equipped with this apparatus and on approximately 2200 miles of double line sections a total number of 10,000 track equipments have been installed. This apparatus is still in service with the present Federal Railway of Western Germany. It has proved its reliable operation during the strenuous years of World War II and after when only a very limited supply of spare parts was available and little maintenance could be spared on this equipment. It is further proved that in many cases severe train disasters could be avoided and heavy damages thereby prevented.

It was possible for Messrs. Siemens & Halske to improve the pre-war system still further in close co-operation with the Federal Railway. Thus according to the concepts of modern manufacture and technique, the vital parts of the equipment could be made much smaller in size, the apparatus could be made suitable for all existing traffic conditions and the power consumption of the engine equipment could be reduced considerably.

What is now the reason for such Automatic Train Control equipment being employed in many technically advanced countries?

The safety in railway traffic and the improvement of the operating conditions has drawn much benefit from the introduction of modern power signalling, by track circuiting of big yards and by Automatic signalling on open line sections. It is, however, known that all such arrangements cannot provide an ultimate protection of the train traffic, since its safety also depends on the watchful eyes of the engine driver. Thereby the human element cannot fully be eliminated, as has been proved by many fateful train disasters.

The driver is compelled to make his driving fully dependent upon the indications of signals. For properly recognizing their position a good knowledge of the section is required. Short sections of slow driving which may be provided permanently or occasionally within the section demand special attention of the driver. On some other sections colour-light signals may change intermittently with semaphores. From all this it may be seen that the driver is fully occupied, since he much pay his utmost attention to the signals and at the same time handle his engine. An error in the former, therefore, is not impossible and has been experienced

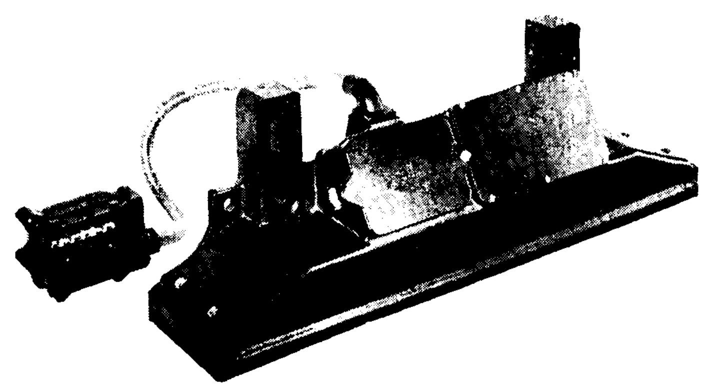


Fig. 1. 3-Frequency Vehicle's Magnet with Plug-in Connection Cable.

* *Signal Engineer of Messrs. Siemens & Halske in India.*

due to the following reasons, mostly leading to major disasters :—

(a) Poor signal view due to foggy or misty weather.

(b) Poor signal view due to smoke from other trains.

(c) Sighting of wrong signals at major yards.

(d) Divertion of driver's attention due to technical faults on his vehicle.

(e) Momentary absent-mindedness or fainting of the driver.

(f) In rare cases even complete neglect of his duties by the driver.

With automatic train control, however, an apparatus is provided which does not require any operation when a signal is passed in 'off'-position, since there is no danger in passing such signal, although for restrictive signal aspects there will be an automatic interference in order to enforce a reduction of the train speed or to come to a stop.

The principle of operation is as follows :—

An electric motor-generator on the engine generates A.C. of 500, 1000, and 2000 cycles p.s. simultaneously. These frequencies are resonated in series with special impulse relay each over impedance coils and condensers, thereby making the current through the relay a maximum. The impedance coils, which are housed together, are mounted at the lower part of the engine on one iron core, thus forming the engine's magnet. (Fig. 1)

On the track at the signal location another magnet, the track magnet is provided the coil of which is also resonated with a built-in condenser for any one of the frequencies 500, 1000, or 2000 c.p.s. (see Fig. 2 and 3). The condenser at the track coil becomes, however, short circuited by an ordinary circuit controller in case of semaphores or a contact of the signal control relay with colour light signals, when the signal is in 'off' position. The track magnet does not require any power supply.

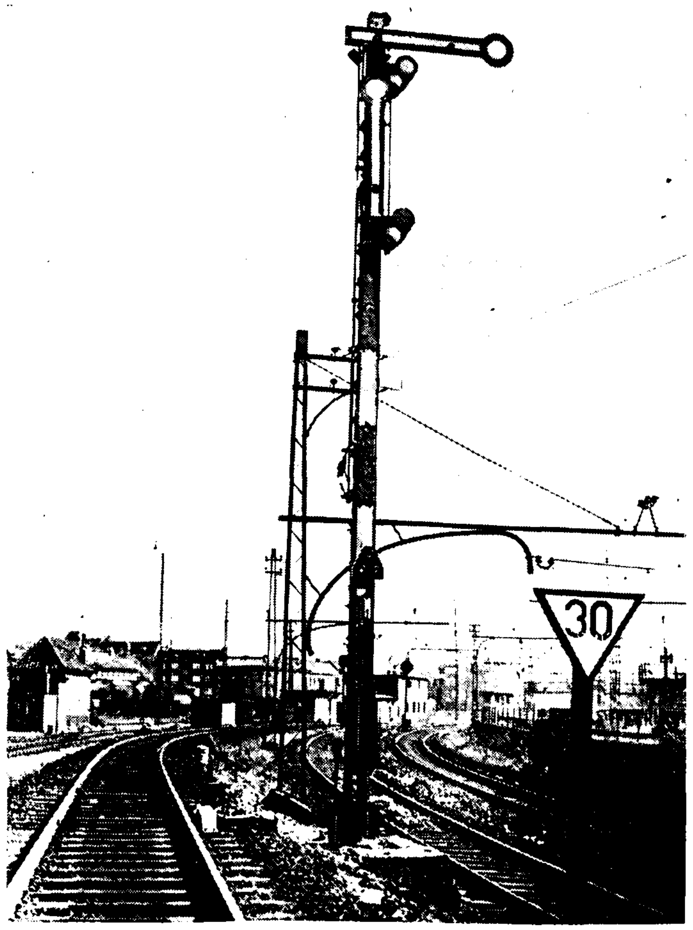


Fig. 2. Track Magnet on Main Signal (Semaphore Type) for 2000 c. p. s.

Fig. 3. Track Magnet for 1000 c. p. s. at mechanical Distant Signal.

By the track magnet being in resonance with the particular frequency of the engine's magnet, enough power is absorbed at the moment when the engine passes to ensure a safe drop-away of the respective impulse relay. Although the time for this seems to be rather short (it may be only 0.0012 second at a train speed of 60 m.p.h.), it will be sufficient for the very sensitive impulse relay, since its current drops to only 20% of its normal hold-up value.

The drop-away of the respective impulse relay at the engine is the first step to release some other relays, which in turn either force the driver to reduce his speed considerably or in case of an absolute stop signal being passed at 'danger' to effect an enforced braking of the train. The relay apparatus will operate a certain air valve. This valve will open the pipes of the air braking system of the train, similarly as the pulling of the chain for the emergency brake.

The operating sequence of Automatic Train control has been laid down for the German Federal Railways in accordance with the operating conditions and train speeds prevailing on this railway. Since the first sections to be equipped with this new apparatus in 1934 were trunk lines with high speed traffic, the 3-frequency system was adopted.

By this system three different phases are observed for influencing a train on the run :—

1. At a Distant Signal showing either caution or attention aspect by the frequency of 1000 c/s.

2. At a distance of approximately 160 yards in the rear of any main signal showing danger or caution position by the frequency of 500 c/s.

3. At an absolute stop signal displaying 'danger' position by frequency of 2000 c. p. s.

In order to enforce a halt of the train at least 220 yards behind an absolute stop signal, which is the maximum overrun distance normally provided on main lines of the Federal Railways, the reduction of speed for trains at highest admissible speeds i. e. 100 miles per hour has to be started at the distant signal. When the train is, therefore, passing a distant signal at either caution or attention position, an automatic transmission must take place at this location. By intercepting the 1000 c.p.s. resonance, the impulse relay will initiate another time relay, a contact of which will delay the enforced breaking for about 5 seconds. This is provided to give the driver ample time to respond by pressing a certain push-button, indicating that he is aware of having passed the distant signal in restrictive position. This button may be called the vigilance button or also acknowledgement key. If the driver, however, neglects to do so, enforced braking will be effected after 5 seconds having passed.

To control that the driver continues his breaking effort after releasing the vigilance button, after further 22 seconds a speed check-up is performed through another contact of the time relay in connection with the speed indicator of the engine. If then the train speed is still above 55 miles per hour, the enforced braking will take place immediately.

By any mistake of the driver it could happen that although he had reduced his speed to below 55 m.p.h., he continues with this speed without reducing further. For this reason, the other speed check-up at 160 yards in rear of the main signal is introduced. The drop-away of the 500 cycles impulse relay will bring about an immediate check of the speed, which, at this point, should not surpass 40 m.p.h. Otherwise, enforced breaking will take place instantly.

The last control will be exercised at the main signal in 'danger' position. There in all cases an enforced breaking will bring the train to an absolute stop by intercepting the 2000 cycles track magnet.

By the described operating sequence with the 3-frequency system, a four-fold control is exercised over the train movement, which again may be recalled as follows :—

(a) Vigilance Test at the distant signal

(b) Speed check-up after 22 seconds restricting the train to a maximum speed of 55 m. p. h.

(c) Speed check-up 160 yards in rear of the main signal at danger, restricting the train to 40 m. p. h.

(d) Enforced breaking at the main signal.

This control seems to be sufficient to ensure that the driver adheres strictly to the signals indicated to him and that the human element is fully eliminated, thereby taking no risks whatsoever.

It may be pointed out that such a system of automatic train control is very flexible and also allows application at level crossings, the gates of which may not be interlocked with the signal. Secondly, it may be used for certain type of cab-signalling, a system which has been adopted successfully in the United States of America.

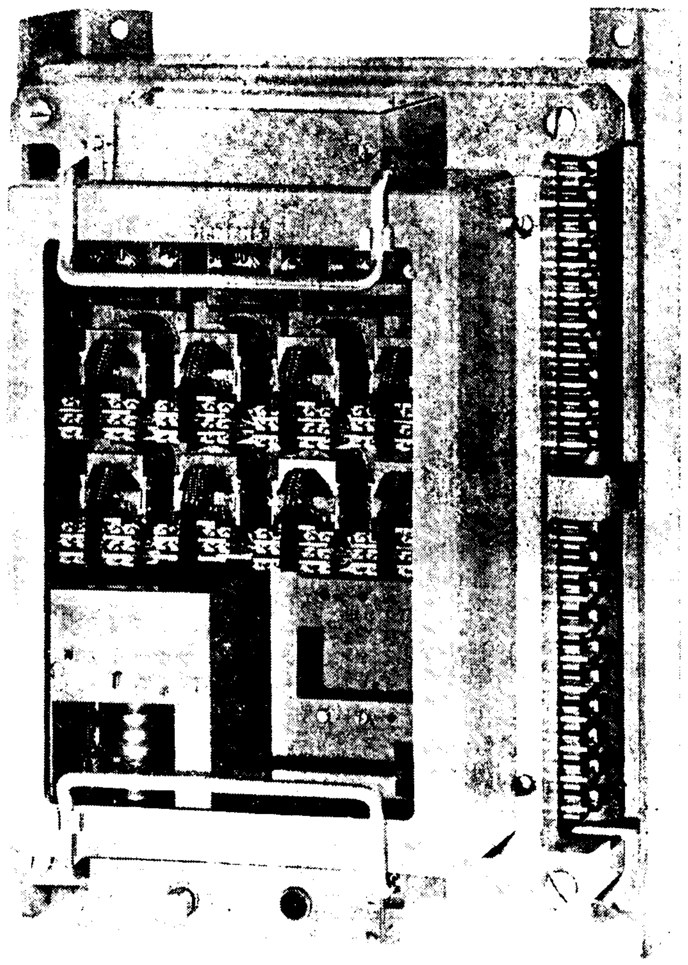


Fig. 4. Plug-in type Relay Unit on Mounting Frame.

The following explanations can be given regarding the equipment in use :—

The three-frequency generator is normally driven by the 24 volts train lighting supply. To ensure constant frequencies, a special governor is provided, which works automatically.

The relay unit incorporates in a plug-in type unit all switching arrangement including the time relay. (See Fig. 4)

The air-brake valve including its switching gear is built into a separate housing, which incorporates also the main switch for the equipment. (See Fig. 5)

The engine's magnets including its coils, condensers etc. are housed in a separate device for which also plug-in type connections are provided.

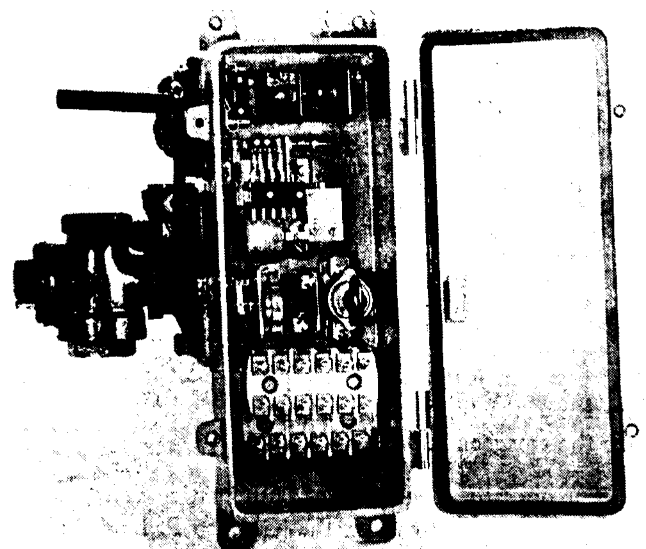


Fig. 5. Brake Valve Unit for Diesel or Electric Trains.

The speedometer is equipped with contacts for certain speeds and provides also a registering device.

The track devices are normally installed on the right hand side of the track, and their resonating frequency is chosen according to the designation of the signal or its location. Thereby main signals are always equipped with a 2000 cycles magnet and in case they should cover any particular danger point a 500 cycles magnet is placed 160 yards in rear.

Each track magnet contains in its casing from light metal alloy its coil on a soft iron core and a high quality capacitor. The free space of the casing is filled up with a special compound from which only connecting cable to a special pothead emerges. From there a short ground cable is lead to the respective signal, over which the capacitor is shorted when the signal is in off position. The track magnet becomes mounted on two sleepers beside the rail. It is supplied already fully resonated and requires no readjustment at the track, since it is not submitted to wear and tear by any mechanical operation.

(Continued on page 43)

BRIDGE ACROSS GANGA NEAR MOKAMEH

Design Considerations for Foundations and Training Works

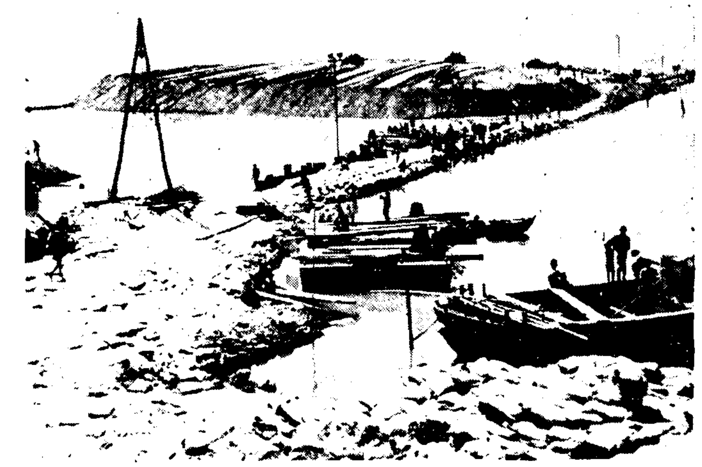
By G. P. Shahani

Engineer-in-Chief, Ganga Bridge Project, Mokameh, District Patna.

INTRODUCTION

(i) *Brief History :—*

THE question of construction of a Railway bridge across the Ganga near Mokameh has been under consideration for very nearly half a century. The Railway Board under their Notification No. 1879-W dated 3rd October, 1945, sanctioned a survey for a combined Rail-cum-Road Bridge across Ganga near Patna or Mokameh Ghat. Mr. J. M. Fenton, who carried out the survey, concluded that from the engineering, financial and subsequent maintenance points of view Mohameh offered a better site than Patna and recommended an early start of the work, as the then river conditions were favourable for locating the Bridge entirely on the main South Channel and sealing the North Channel. Soon after Mr. Fenton submitted his report, an independent organization was set up at Bridge site (at Hathidah) directly under the Railway Board, in charge of an Engineer-in-Chief, to construct the Bridge and other connected works. While the preliminary works were still under way, unusually heavy floods of 1948, (14th September, H. F. L. 141.1, maximum velocity 14.66 ft./sec. discharge 24,48,900 cusecs) developed the North Channel (proposed to be sealed)—North Channel discharge 14.03 lakhs cusecs 57%, South Channel discharge 10.46 lakhs cusecs 43%. This heavy flood very materially altered the site conditions calling for a fresh assessment of the situation. The Bihar Government also pressed hard Patna's claim for a Bridge in preference to the one proposed at Mokameh.



Sealing of North Channel—Earth being dozed in 11 ft. depth of water between stone dykes previously constructed near the Up & Down Stream Toes of the Bank.

View of Guide Bank—Protection of Front Side Slopes with 9" quarry refuse and 3½ ft. thick boulders hand-packed.

(Continued from page 42)

The described system of Automatic Train Control has proved to work successfully on the German Federal Railways. Other, eventually less elaborate systems are used by other railways of the world. Another much simpler system working on the magnetic principle has also been developed by Messrs. Siemens & Halske and is mostly employed for secondary railways with lower speeds or for suburban traffic only.

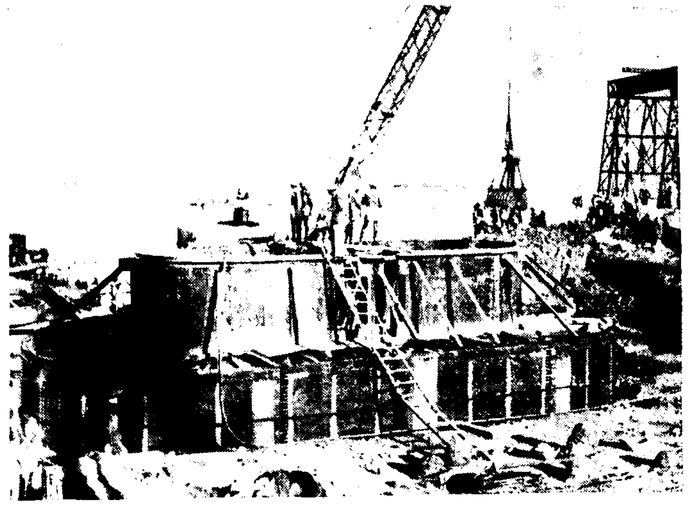
The expenses for introducing Automatic Train Control will be heavy at the beginning, but they will certainly result in an overall reduction of accidents, if not even avoid major train disasters. They will also enable the railways to run certain trunk trains at highest speeds without taking too much risk from the signalling side. It is, therefore, believed that Automatic Train Control must have some future on the Indian Railways.

The ways and means position of the Government of India, immediately after the Partition also became difficult. All these factors combined resulted in the postponement of the work; this presented another chance to consider the entire matter afresh, particularly the changed river conditions (which channel to bridge upon?). It was decided not to discontinue—

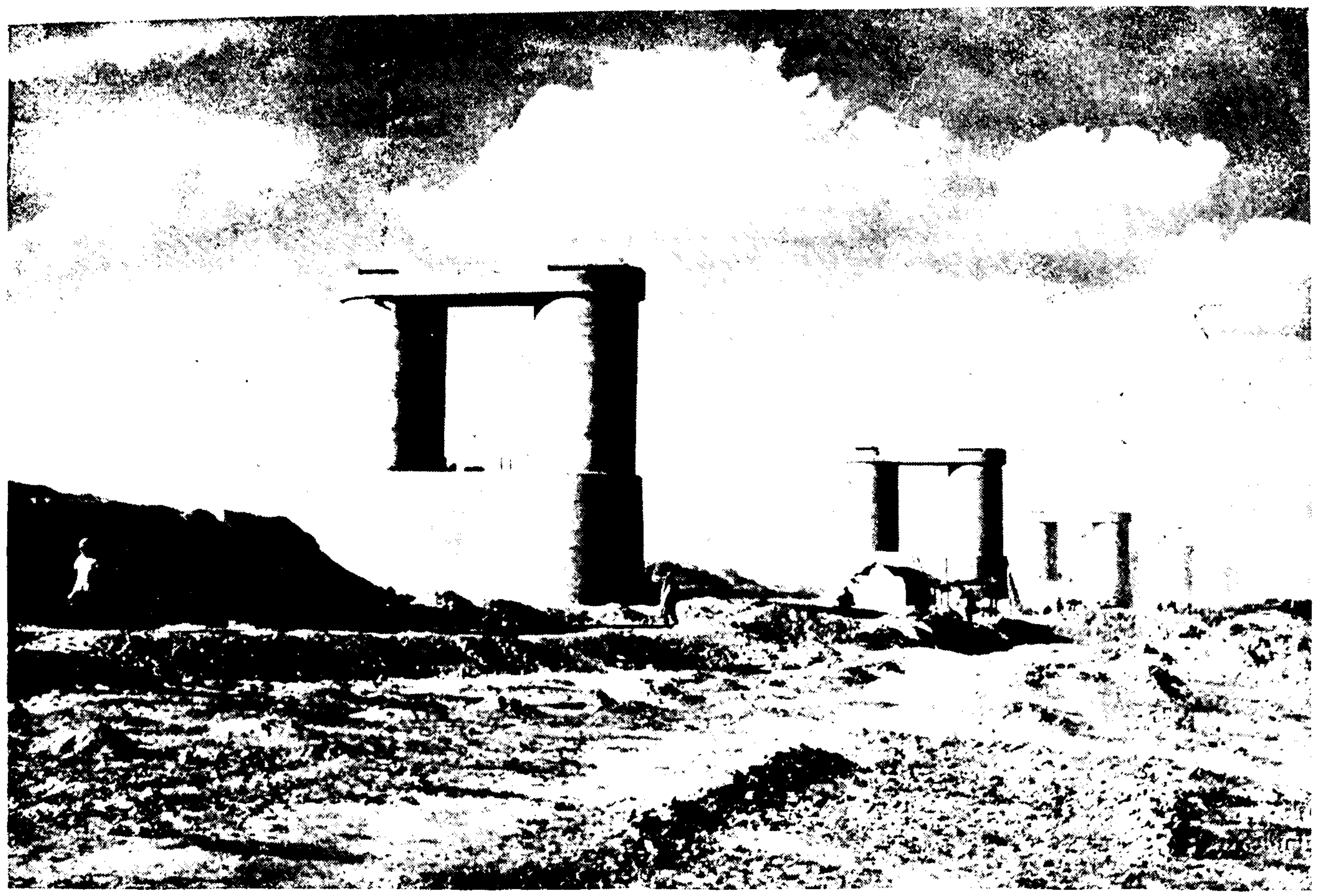
(a) the study of river conditions and collection of hydraulic data, and

(b) the experiments on a model scale at the Central Research Station near Poona to determine the optimum length and correct design of the Guide Bank and its effects on the South Bank.

The partition of the country and the construction of the Assam Rail Link changed the trends and flow of traffic to and from North Bengal and Assam. The old Broad Gauge Bengal Assam Railway route for all practical purposes ceased to exist. With the very materially changed conditions in the country the most suitable site for a bridge across Ganga had to be examined afresh. The Government of India under their letter No. E 52 COI/6/3 dated 28th March, 1952, invited the veteran Engineer Bharat Ratna Sir M. Visveswaraya to go into the whole question.



M.S. Well Curb with Strake Al in position. Note the two Dredge Holes.



Main Piers 15 to 11 completed upto bed stone level. Top of cap at R.L. + 172. Base of 15 ft. dia. reinforced concrete cylinders at R.L. + 143.

As a result of his investigations and enquiries, Sir Visveswaraya adjudged Mokameh as the most suitable site for the proposed Bridge.

In September, 1953, once again an independent organization under the Railway Board came into being at Hathidah, in charge of a General Manager & Chief Engineer to resume construction of the proposed Rail-cum-Road Bridge and other incidental works.

(ii) *Justification :—*

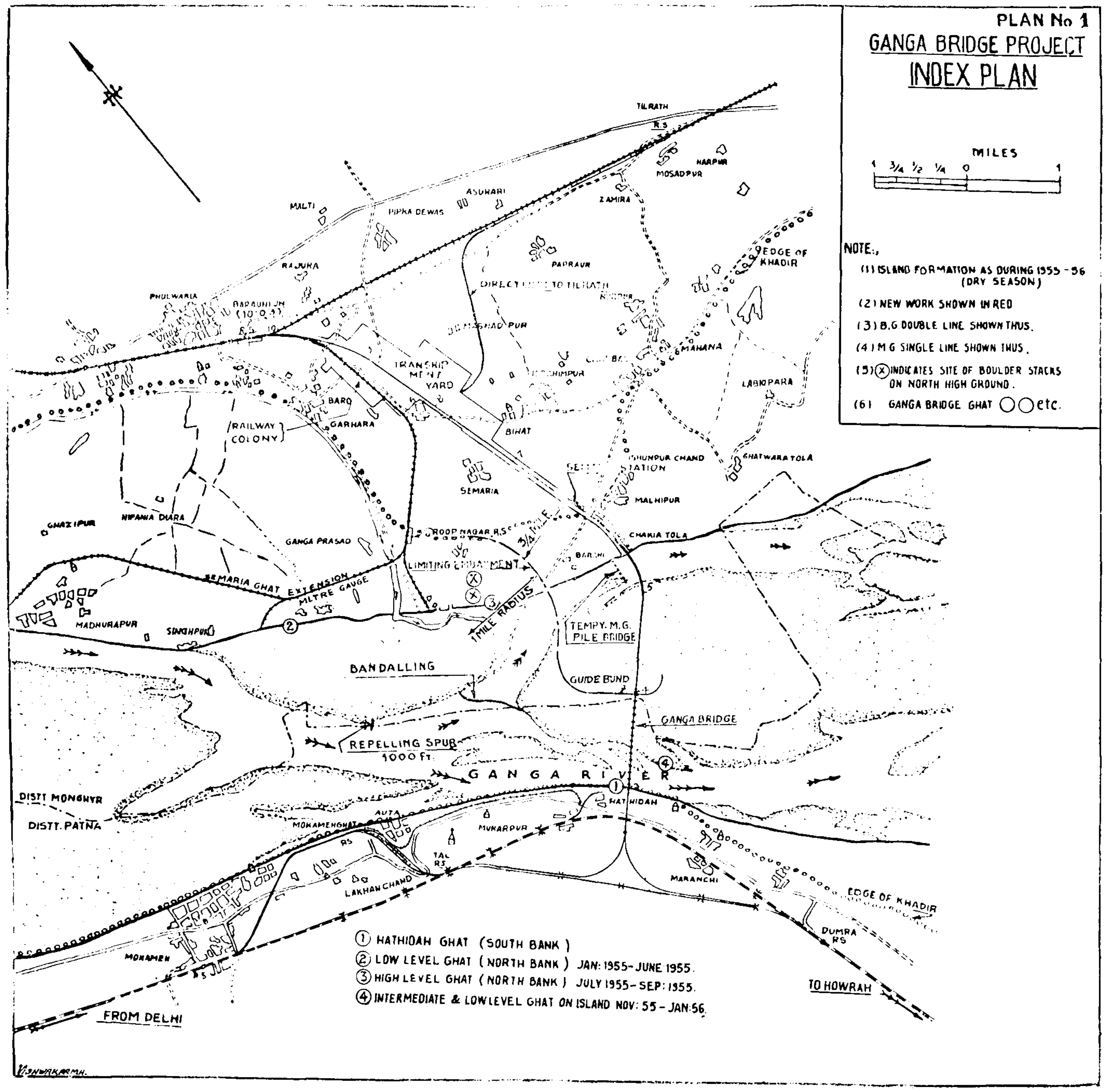
River Ganga divides Bihar into two regions, North Bihar and South Bihar. North Bihar is mainly an agricultural area; its principal industry is sugar, the annual production being about 200,000 tons. South Bihar is also agricultural, but its importance lies in its mineral wealth and industries. It has got its iron & steel works at Tatanagar, Cement Works at Dalmianagar and Japla, and coal in a number of collieries on the Eastern and South Eastern Railways. The economy of North Bihar depends mainly on the seasonal rainfall. Any shortage in rainfall turn it into a deficit area or even into a famine one. South Bihar supplies to North Bihar its essential supplies of steel, coal, cement, lime, etc. The mighty river Ganga has been a great barrier between the two Bihars and crossing the river in country-boats particularly during floods is a hazardous task.

There are four Railway worked ferries to handle the passenger and goods traffic between Calcutta and South Bihar on one side to North Bihar, North Bengal and Assam on the other. The ferries however well worked, due to their inherent limitations result in detention to wagons, unnecessary handling of all consignments with possibility of damage, etc., besides the frequent shifting of Ghats to suit the ever changing moods of the river which lead to hold-ups and loss of capacity. Severe restrictions are imposed from time to time on the movement of goods. At Mokameh Ghat even the passengers take over an hour to cross the river. It takes the passengers nearly 2½ hours to cover a distance of about 8 miles between the two rail heads at Mokameh Ghat (B.G.) and Barauni (M. G.). The goods get detained days in transit and some times suffer damage in handling. The present capacity of the goods ferries in service at Mokameh Ghat is about 250 M. G. wagons per day. The Bridge and the BG./MG. Transhipment

Yard, when completed, will be capable of handling about 1000 M. G. wagons per day. Financial consideration and return on capital cost apart, the Bridge is essentially required to connect North and South Bihar with a permanent all-weather Road-Rail Link. The Bridge when completed will replace the inefficient and expensive wagon ferries at Mokameh Ghat and will increase by at least four fold the transport capacity and thus help in an all-round development of North Bihar.

(iii) *River Ganga* :

The river Ganga, sacred to the millions of Hindus residing all over India, rises in the Gangotri glaciers of the mighty Himalayas and has a total catchment area of about 3,92,000 square miles.[1] Her important tributaries are the Ramganga, Gumti, Gogra, Gandak, Kosi[2] on the left bank and Jamuna & Sone on the right bank. After traversing a total distance of about 1569 miles



1. Catchment area upto the Bridge site is 2,93,000 square miles.

2. Kosi merges into Ganga below the Bridge site.

through the States of Uttar Pradesh, Bihar, West Bengal and East Pakistan, the river falls into the Bay of Bengal. At Mokameh the river is well advanced in the alluvial stage being about 1048 miles from the source. It has considerable river traffic. The river is subject to heavy flooding during the monsoon season. The dry weather discharge may be as little as 45,000 cusecs at about 3 feet per second (March-April period), but actual flood discharge of nearly 25,00,000 cusecs has been recorded with a maximum velocity of about 14.66 feet per second (14 9—1948).

(iv) *Bridge Site :—*

The Bridge site, latitude 25 —22′ North and longitude 86 East, is about 5¼ miles downstream of Mokameh Junction situated on the Main Line of Eastern Railway. It is about 270 miles from Calcutta and about 61 miles East of Patna. The bearing of the Bridge is very nearly North East.

(v) *Data for Design :—*

Loads—All the loads specified in the Bridge Rules and Road-cum-Rail Bridge Code have been provided for.

(i) *Live Loads—*

(a) *Railway*—Broad Gauge, Main Line Standard (Single Track)

(b) *Roadway*—AA Highway Loading single train or two trains A Class Loading, whichever controls. The clear width of the roadway is 24 feet.

(ii) *Footpaths*—Two footpaths, each six feet wide have been provided. The loading is as specified in the Bridge Rules.

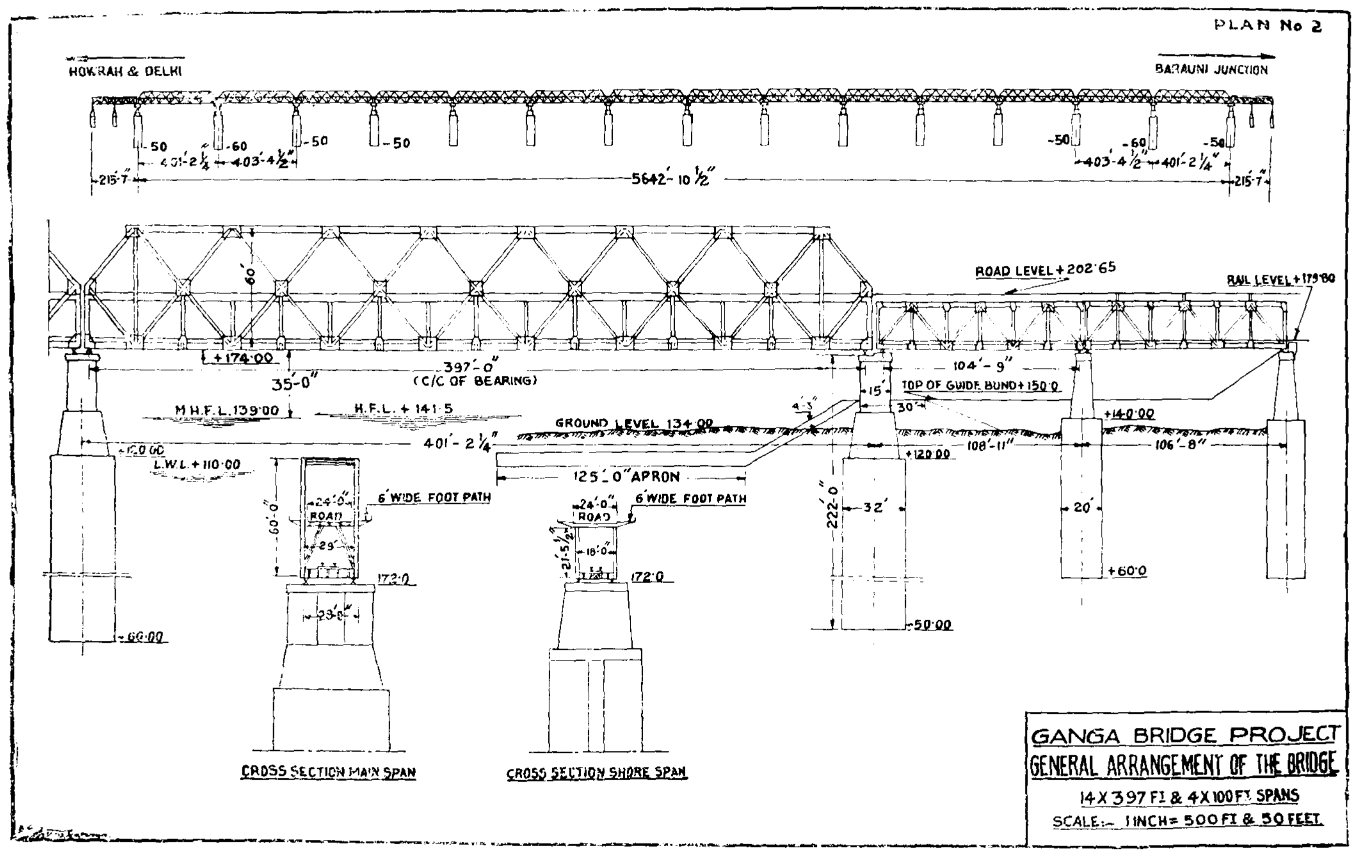
(iii) *Other Loads*—In addition to the usual dead loads, provision has been made for an additional 320 lbs. per foot length of the bridge on account of cables, mains, etc.

(iv) *Seismic Loads*—A horizontal acceleration of 3.2 feet per second has been allowed for. This has not been combined with wind force, but the Bridge has been designed to resist either of the two, whichever is greater. For the design of Piers, including well foundations, longitudinal forces have not been combined with seismic forces.

FOUNDATIONS

(i) *Discharge :—*

Following discharge observations have been recorded at the Bridge site near Hathidah :—



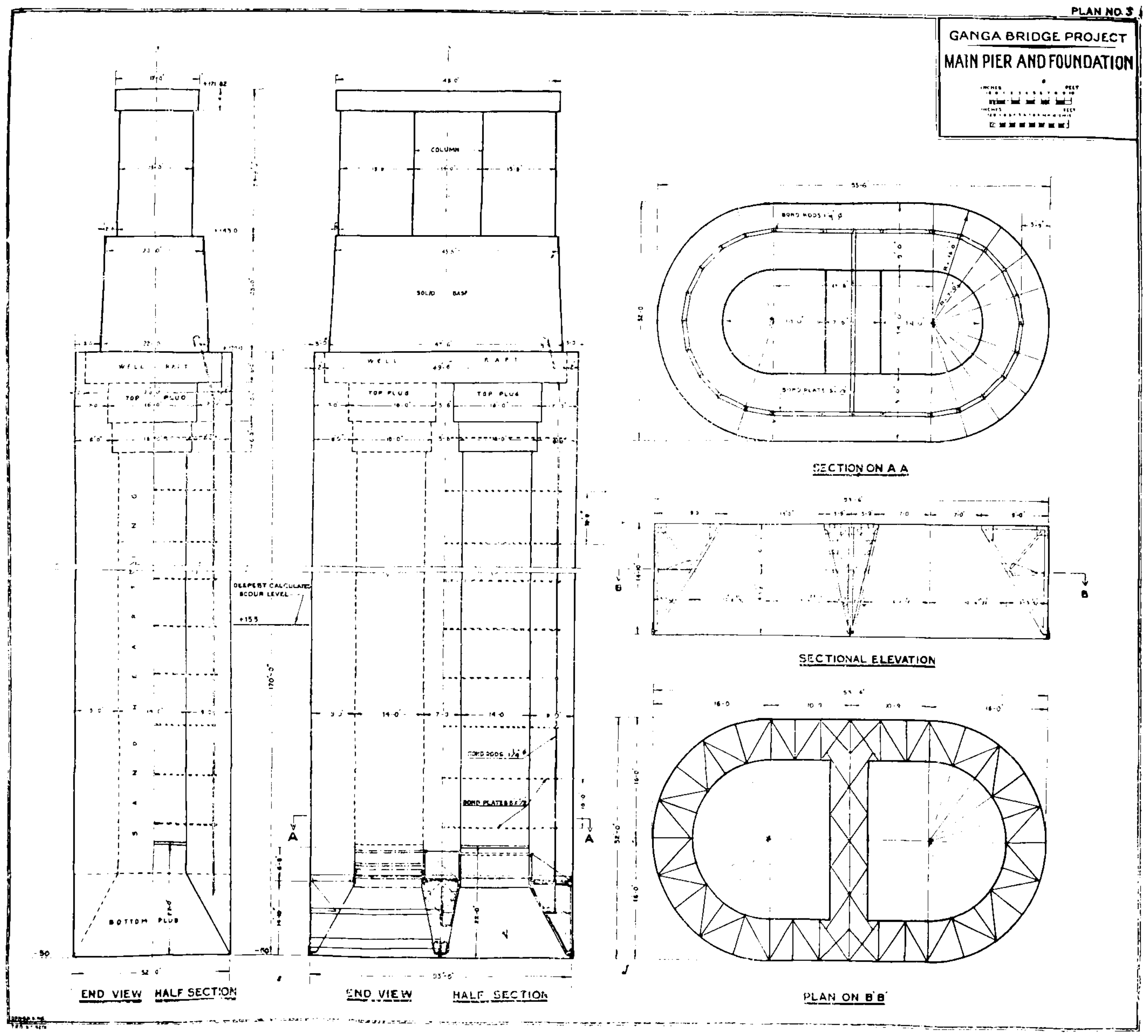
Date	Flood Level	Width of waterway in feet	Maximum velocity in ft./sec.	Cross sectional Area in Sq. ft.	Discharge in cusecs	Mean Velocity in ft./sec
14-9-1948	141.10	11,700	14.66	3,11,300	24,48,900	8.30
19-9-1948	140.60	11,650	13.66	2,90,400	24,06,600	8.28

The Highest Flood Level is (141.5 (1918) or 0.40 feet higher than the level touched on 14-9-'48. This much rise in flood level would add to the measured discharge of 24,48,900 cusecs about 68,609 cusecs (0.4×14.66×117000) making the total maximum discharge of the river equal to about 25,17,509 cusecs.

The total catchment area of the river upto the Bridge site is about 2,93,000 square miles. The maximum discharge of the river as per the "Peak Flood Envelope Curve for Rivers of the World" evolved by the Central Water Power, Irrigation and Navigation Commission is about 26,00,000 cusecs which is nearly the same as deduced from the actual Discharge Observation above. The Bridge has been designed for a peak discharge of 27,50,000 cusecs.

(ii) *Waterway* :—

As per Lacey's regime formula, for the alluvial rivers $L_W = 2.667\ Q^{\frac{1}{2}}$, where L_W is the net waterway required in feet (more correctly the wetted perimeter) and Q is the maximum discharge in cusecs, the net waterway works out to 4421 feet. The Bridge consists of 14 main spans of 403.4 feet overall length each; 13 spans have



been taken as effective, one has been added to compensate for the obstruction created in the two end spans by the training works (on the North end of the Bridge) and the firm clay ledge (on the South end of the Bridge). The net clear waterway actually provided under the bridge is 4412.2 feet against Lacey's requirements of 4421 feet as under :—

Gross Length	13×403.4	=	5244.2 feet
Deduct for the pier obstructions	13×32×2	=	832.0 ,,
(twice the width of wells).			4412.2 feet

(iii) *Deepest Scour* :—

As per Lacey's regime formula for scour in alluvial rivers, $S = C \times 0.472 \left(\frac{Q}{f}\right)^{\frac{1}{3}}$ where 'f' is a factor expressing the erodability of the materials constituting the bed of the river and C a factor varying from 1½ to 2 in accordance with the type of bridge site. The factor C is given as 1¼ in the case of a symmetrical section with a straight reach increasing in gradually worsening conditions to a maximum of 2 for Spring's "right angle bed" where the direction of the main current is assumed to pass from the head of one guide bank to make a frontal attack on the other. Mr. J. M. Fenton has worked out the value of the deepest scour as 126 feet below H. F. L. of +141.5 assuming the value of 'f' as 1.15 and C = 2 i. e. to R. L. + 15.5.

In the Mokameh reach observations for the deepest scour were carried out during 1945–46 and 1946—47 dry seasons. It was observed to be 38 feet below the low water level (+110.00). According to Gales, greatest anticipated scour would be :—

Observed scour below L. W. L.	38 feet
Add 33% for hard bank	13 feet
Deepest known scour	51 feet

Deepest known scour	51 feet
Add 45% for proximity of Guide banks for C Class rivers	23 feet
	74 feet
Add difference between L.W.L. and H. H. F. L.	32 feet
Total below H. H. F. L.	106 feet

This figure, being less than Lacey's viz. 126 feet, has been discarded in favour of the latter for determining the depth of foundations.

(iv) *Depth of Foundations* :—

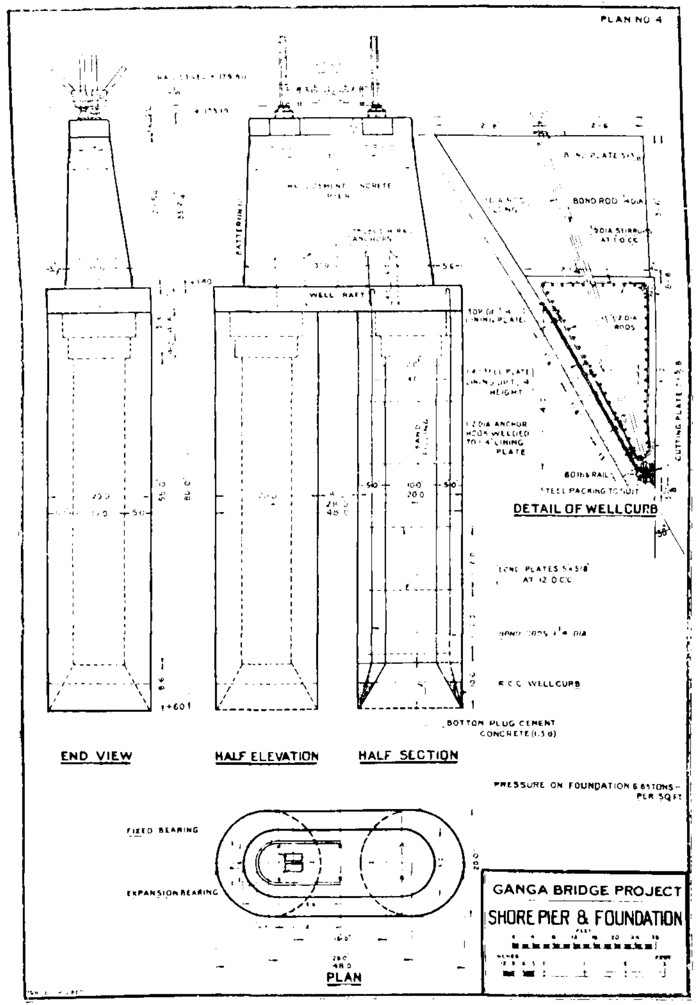
For secure and stable foundations it is obvious that there should be adequate embedment of the wells beyond the deepest possible scour. The accepted standard practices for this additional grip beyond the deepest scour are tabulated below :

	Depth below H.H.F.L.	*Reduced Level*
Maximum scour	126 feet	+15.50
Roads Congress add 33-1/3%	168 ,,	−26.50
Spring—add 50 feet	176 ,,	−34.50
Gales—add 65 feet	191 ,,	−49.50

The lowest foundation level as per Gales' recommendations has been adopted for the Bridge. All main piers have been founded at R. L. −50.0 except piers No. 2 & 14 which have been sunk to R. L. −60.00 or 10 feet deeper to counter the extreme scour conditions which are likely to be experienced in the vicinity of the training works.

(v) *Main Piers* :—

The important features of design adopted for the main piers and wells are illustrated on Plan No. III. The wells under the main piers are 53 feet 6 inches long × 32 feet wide with semi-circular ends. Each well has two D-shaped dredge holes. The mild steel well curb is 14 ft. 10 inches high and weighs about 125 tons each. On top of each well curb at least one length of mild steel strake is to be added, type AI (about 13.3 tons) for the land piers and type A (about 34 tons) for the water piers. On the inside face of these strakes (A/AI) has been fixed a cast steel ring



to seat the "Adapter" in case well sinking under air pressure became necessary[1]. For the water piers the height of caissons is increased, to suit the depth of water, with the addition of B type (about 34 tons) strakes[2]. It will be noticed from Plan No. III that the total height (about 52 ft.) of pier over R. C. cap has been made up partly in mass concrete (solid) upto R. L. +143.00 (above the H. F. L. of +141.5) and above this it consists of two R. C. cylinders 15 feet diameter each. On top of the cylinders is a 4 feet thick R. C. cap in which are embedded the M. S. Grillages which will directly support the bearings. It was necessary to adopt the twin R. C. cylinders for the pier-design to keep down the weight of the piers as far as possible, so as not to increase unnecessarily the foundation pressure which is already as high as 13.6 tons/sq. ft. at R. L. −50.00[3]. Gross area of the well

1. During the first 1955-56 working season, 7 main piers have been completed ; it was not found necessary to resort to pneumatic sinking of wells at any stage
2. If D be the depth, total height of caissons required was $1\frac{1}{2}$ D.
3. Gross without any allowance for skin friction or buoyancy, net would be about 6.2 tons/sq.ft. Gross foundation pressure for Hardinge Bridge is 13.0 tons/sq.ft. and at Wellingdon Bridge it is 11.5 tons/sq.ft.

works out to 1493 square feet. Thickness of concrete steining has been kept 9 feet to get a good sinking effort even without any additional kentledge for the depth of sinking desired—it works out to a minimum of about $7\frac{1}{2}$ cwts. per sq. ft. in the last stages of sinking.

The Bridge is situated in region of considerable seismic activity; serve earthquake have in the past devastated large tracts in Bihar, one of the recent ones being dated 15th January, 1934. The piers have, therefore, been designed for an horizontal acceleration of $\frac{g}{10}$. Cement concrete of 1500 lbs. sq. inch strength (28 days) has generally been used for the mass concrete in steining of wells, except for 20 to 30 feet from R. L. +10 to +0 R. L. +30 which is of 2400 lbs./sq. inch strength (28 days)[1]. This was done to meet the requirements of the seismic forces at the maximum scour level of +15.5. The other alternative was to use steel reinforcement in this portion of the well steining to develop tension. It was decided not to use reinforced concrete in the steining, but to adopt a richer mix.

PRESSURE AT BASE

Total weight on foundations is 20,342 tons as under :

(a) From Live Loads (Rail & Road, without impact	1476 tons	7.2%
(b) From Dead Weight of Girders, bearings, track and road decking	1548 ,,	7.6%
(c) From Pier (Superstructure)	2020 ,,	9.9%
(i) 4′ Pier Cap 185 tons		
(ii) 2 Cylinders 15′ dia. 570 ,,		
(iii) Solid Base 1265 ,,		
(d) From Well Foundation	15298 ,,	75.2%
(i) 6′ deep well raft & steining 575 tons		
(ii) Top Plug and steining 1305 ,,		
(iii) Weight of steining 10730 ,,		
Total	20342 tons	

1. For Piers No. 2 and 14 from R.L. + o to R.L. + 30
For Piers No. 1, 3 to 13 & 15 from R.L. + 10 to R.L. + 30.

B. F.		20342 tons
(iv) Weight of bottom plug	480 ,,	
(v) Weight of sand filling	1990 ,,	
(vi) Weight of bond rods & plates	218 ,,	
Total		20342 tons

Average Foundation Pressure $\frac{20342}{1495}$ = 13.6 tons/sq.ft.[1]

From the above it will be observed that by the time pier is completed to its full height the foundation is already bearing about 85.1% of the final design pressure of 13.6 tons/sq. ft. and that the contribution of both the live loads (Rail and Road) is negligible being only about 7.2%.

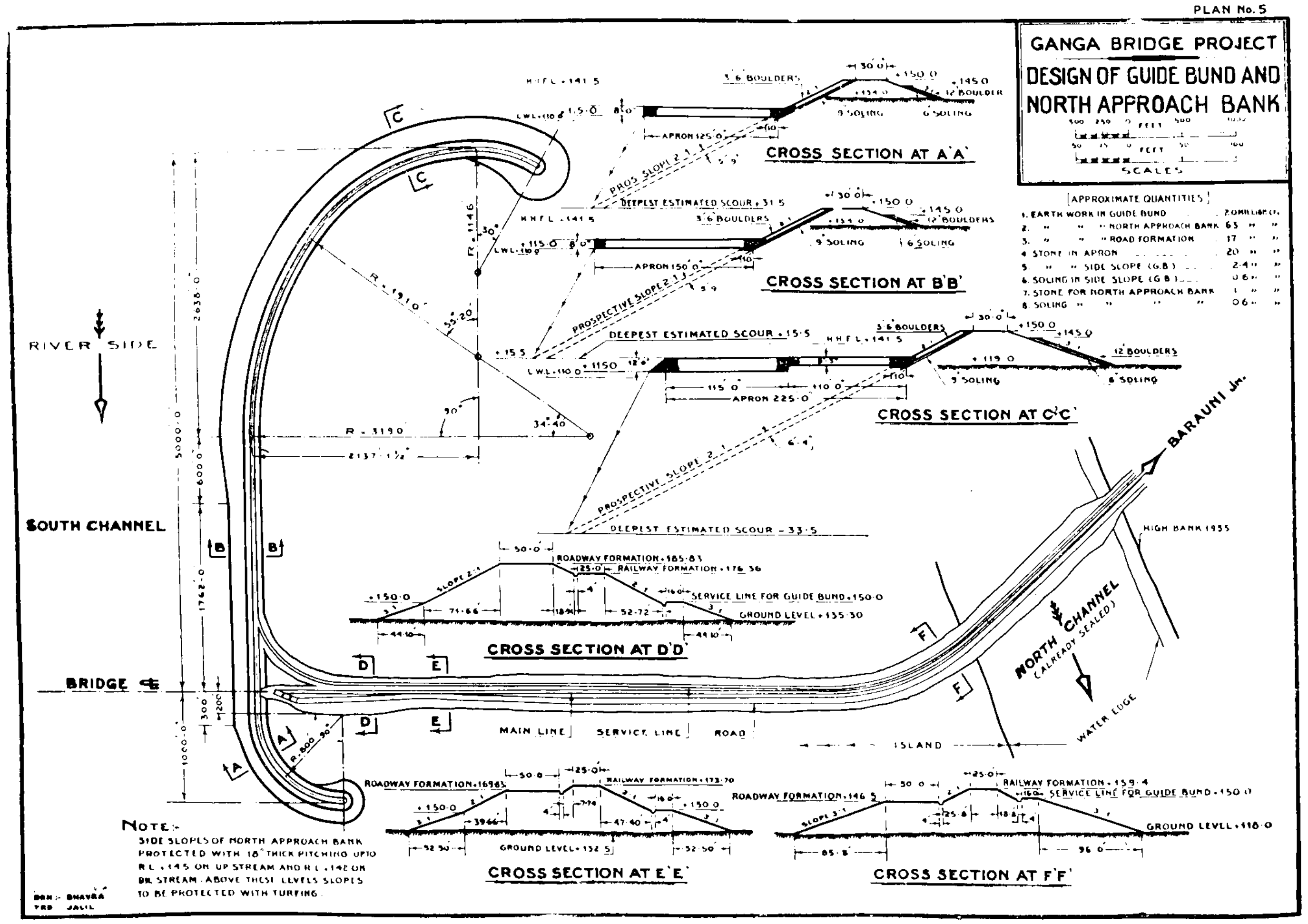
(vi) *Strata :*

Deep trial borings to R. Ls well below —100.00 were carried out in the river bed and on the island near the Bridge Centre Line to investigate strata likely to be met with during the course of well sinking and at the proposed foundation levels of —50.0 and —60.0. The work was carried out by contract at an estimated cost of Rs. 4.48 lakhs for a total of 53 trial borings. The results[2] indicated that the foundations will have to rest on medium to coarse sandy soil which may be mixed with kankar nodules. Confined sandy soil has a good load bearing value.

(vii) *Shore Piers :*

The details of the design for the land piers and foundations are given on Plan No. IV. The foundations consist of 2—20 ft. dia. wells (thickness of steining 5 feet) sunk at 28 feet centres R. L. +60.00. The gross average pressure on foundations works out to 6.63 tons/sq. ft.[3]

PLAN No. 5

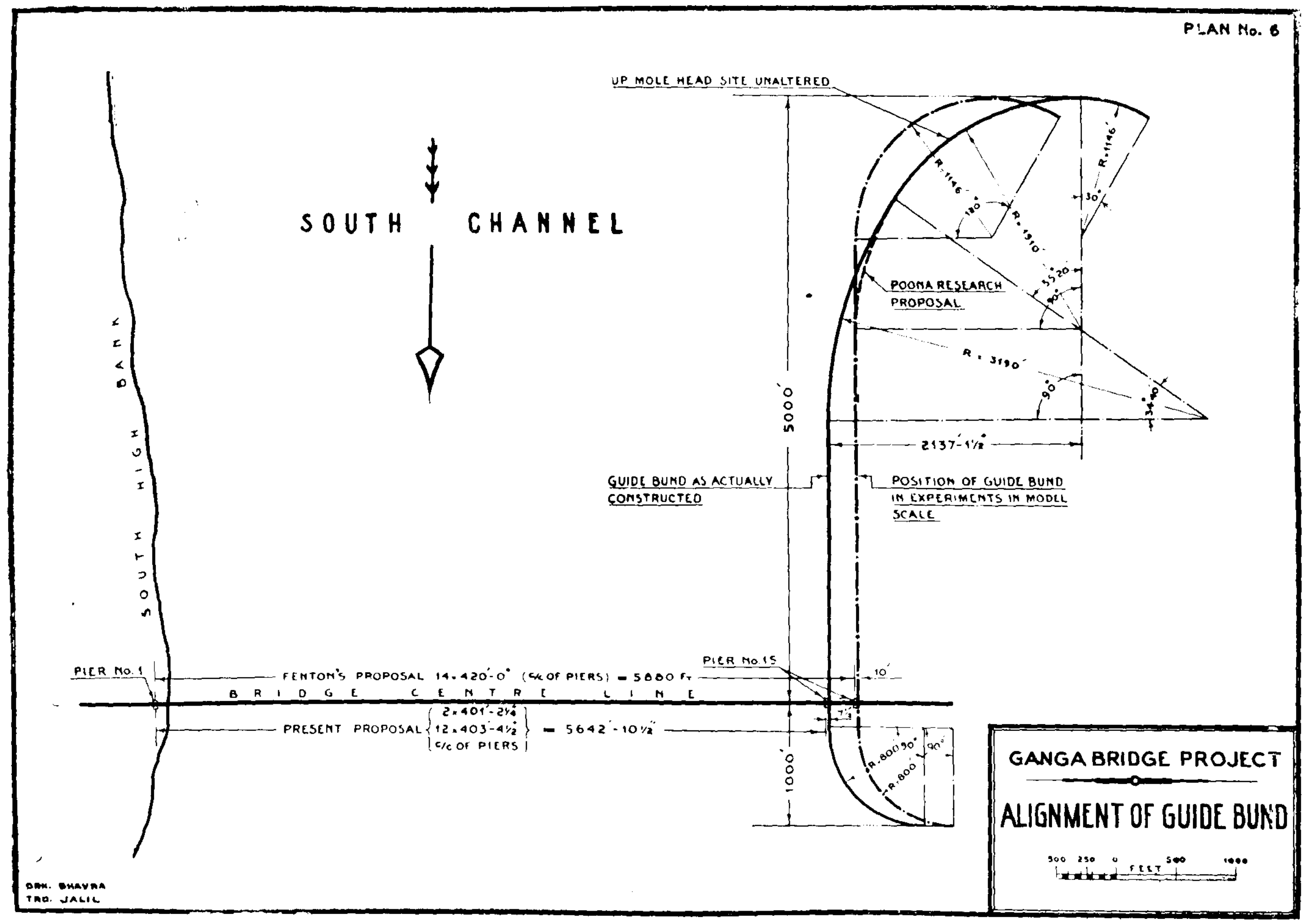


1. For the wells sunk in correct position and in plumb.
2. The results of the trial borings have since been confirmed by actual observations of the dredged materials from the seven wells since completed.
3. For the wells sunk in correct position and in plumb.

TRAINING WORKS

(i) *Waterway* :—

The unrestricted waterway at the Bridge site at mean flood level of about R. L. +138.5 is about $2\frac{1}{4}$ miles between the South Bank and North Bank. The South Bank consists of indurated clay[1] and defines the right edge of khadir of the river[2]. It has withstood the floods of many a decade past. The North Bank is overtopped and damaged; it lies well within the left edge of the khadir. On the left Bank some villages (Madhurapur, Chakiatola) which were built many years ago a good distance away from the then river brink, have been washed away. The villagers saved what they could from the hungry and angry river and moved further back. Those who live on the bank of a mighty river like the Ganga, are familiar with the painful sight of huge chunks of land falling in the roaring waters. They take this along with the greater blessings of the river.



1. *Indurated Clay*—Under certain conditions, both during flood and afterwards as the flood waters fall, an alluvial river deposits the materials held in suspension, the heavier material such as the coarser sand being deposited first, and then the more imponderable and very fine silt. As mentioned above, the deposition of silt on diara land is a constant occurrence but, if conditions are fortuitous, an old channel abandoned by the river may be filled with fine silt from quite a low level. If it so happens that the river makes no attempt to return to the channel for a very long period of time, conditions are then favourable for the silt to become hardened or indurated. Eventually, when the main channel of the river does approach its former bed, it finds an impenetrable clay barrier which halts its further advance in that direction. The process of induration is due to the expression of surplus moisture and the binding of the silt by carbonates of lime, silicates of magnesium, aluminium and iron oxide & c. The carbonate of lime often appears as separate kunker nodules or kunker belts. Indurated silt is, geologically, not a true clay but may nevertheless exhibit high qualities of toughness and inerodability. *(From Mr. J. M. Fenton's Report)*

2. *Khadir*—The khadir of an alluvial river is that width between which the river meanders and every portion of which it will from time to time occupy. The edges of the khadir are usually of stiff clay which for periods normally considered in connexion with engineering schemes, may be considered as inerodable. The river may and very often does spill over the edges of its khadir but the meanderings of the main channel do not wander beyond them. The term khadir is variously employed to describe the width between the permanent banks as well as the permanent clay banks themselves. *(From Mr. J. M. Fenton's Report)*

Near Mokameh Ghat the meanderings of the river are the minimum width of the khadir being the least. Shortly downstream of Barh it is six miles, increasing to nearly eight miles opposite Pandrak Railway Station, from which point its value reduces to five miles opposite Mokameh Ghat. Here the left bank khadir approaches the right rapidly, so that for a further distance of almost three miles the width of khadir is reduced to a little over two and a half miles. Subsequently, the edges of the khadir diverge considerably and at a distance of ten miles further downstream, the khadir width becomes ten miles. The Bridge has been sited on this gorge in the khadir, as much down as possible, so as to provide the maximum regulative effect on the river as well as to reduce the severity of potential attacks on the training works. The Bridge has been located at the extreme south end of the khadir across the South Main Channel; advantage has thus been taken of the firm South Bank to serve as the South flank of the bridge. It has been proposed to construct only one Guide Bank at the North end of the bridge. It is fortunate that the conditions are such that only one Guide Bank will do, at least to begin with and may be for many a year to come.[1] The quantities of work involved in even one Guide Bank are enormous (over 2 crores cubic feet of earthwork and over $2\frac{1}{4}$ crores cubic feet of pitching stone) to complete in the limited space of a brief working season of about 200 days or so. Completion of two guide banks in one season would have been an impossible task. Had the local conditions dictated the necessity of two guide banks, it might have been necessary to construct them in more than one season with temporary mole heads. The gross waterway under the main spans to 5547.6 feet (14×403.4 feet) and the net waterway works out to about 4412.2 ft. (Para II (ii)).

(ii) *Training Works* :—

The training works consist of—

(i) a Guide Bank on North end of the Bridge and at right angles to it, and

(ii) effective sealing of the North Channel with a winter discharge of about 5000 cusecs.

A Guide Bank has two purposes to fulfil, one to guide the flow of water smoothly without undue eddy formation or severe attack on the opposite bank and to induce the flow more or less axially through the bridge opening and secondly to afford protection on the approach bank against embayment.

The Guide Bank (Plan No. V) has its crest level at R.L.+150.0. It has a top with of 30 feet with front side slope of 2 : 1 and the back side slope of 3 : 1. The river side slope is protected with 9" of quarry refuse and $3\frac{1}{2}$ feet thick hand packed pitching. The rear slope has been protected against wave-wash with 6" quarry refuse and 18" stone pitching upto R.L.+145.00. The width of apron varies from 125 feet to 225 feet with depth of stone filling 8 feet to 12 feet[2]. The Guide Bank extends 5000 feet (0.885L) on the upstream side and 1000 feet (0.177 L) on the downstream side.

The length of the guide bank both on the upstream and downstream is less than the usual accepted standards of L to $1\frac{1}{2}$ L on the upstream side and $\frac{1}{4}$ L to $\frac{3}{8}$ L on the downstream side of the Bridge. In view of the enormous effort and cost involved in the construction of the guide bank and the limited time within which it must be completed, it was decided to carry out experiments on a model scale at the Central Water and Power Research Station, Poona (a) to determine the optimum length of the guide bank on the upstream side, (b) to study its disturbing effects on the South Bank, and (c) to finalise the most suitable curvature for the upstream mole head, keeping in view both the economy in cost and eddy formation. A model covering a reach of about 50 miles above the bridge site and 17 miles below, was constructed with 1/560 horizontal

1. Opinion expressed by Mr. Fenton—"Where, as is the case at both the Patna and Mokameh sites, the khadir, utilised as a natural training bund, extends a considerable distance upstream of the bridge site without any abrupt change in its general direction, an artificial training bund on the other flank of such a bridge is extremely unlikely ever to be subject to a high degree of oblique attack. In fact, apart from the head of such a training bund, the body and tail would be for less vulnerable than in the case of a bridge with two artificial training bunds. The edge of the khadir itself would, of course, be subject to the full obliquity of attack occasioned by a limiting position of an embayment behind the head of the artificial training bund, but it is assumed, and the writer feels confident in this assumption, that the clay of the khadir even at Mokameh is fully capable of withstanding such conditions without significant damage for many years to come".

Sir Claude Inglis's opinion—"I do not object to this, because I consider it is possible to design the North Guide Bank so that no direct attack will develop towards the south bank; but should the design be such as to allow a direct attack on the south bank to develop, the position would be very serious. This is a point I feel I must stress." ......

2. Guide bank has been constructed with 35 feet top width to suit the manoeuvrability of the Earthmoving Plant. Due to late floods and higher water levels this season the bed of apron has been kept at R.L.+118.00 instead of R.L.+115.00 originally proposed. The width of apron has been increased to suit. Dumping of stone in apron could not be postponed beyond 15—12—55 - Water Level 118.3.

scale and 1/67 vertical scale. The bridge alignment as proposed in the Project was confirmed, as it is very nearly at right angles to the general direction of the currents. The angle between the current direction and the bridge alignment in the South Channel was between 86° and 90°. For the upstream length of the guide bank, lengths of 4500 feet, 5000 feet and 5500 feet were tried on the model. The length of 5000 feet was found to be the most suitable. The longer length of 5500 feet directed a strong current against the unprotected south bank and was thus undesirable. Also with a length of 5000 feet the flow through the bridge spans was found to be more uniformly distributed. This has the advantage that none of the pier foundations will be subject to an undue concentration of flow resulting in very deep scour. Shorter guide bank of 4500 feet length was found to give insufficient protection to the approach bank.

Experiments were carried out with 3° and 5° curves for the up mole-head. The water was noticed to cling better to the Guide Bank with the 3° curve due to its easier and smoother curvature; there was lesser eddy formation and also lesser throw-off than in the case of 5° curve, thereby making the conditions near the unprotected south bank more safe. Reduction in the eddies also reduced the depth of scour near the mole-head. Flatter curve meant longer length and therefore a more costly guide bank for the same subtended central angle. It was, therefore, decided to adopt 3° curvature for the inside 90° sweep, leaving 5° curvature for the outer 30° sweep of the mole-head. The extra cost involved may well be justified for the better hydraulic conditions, namely the higher concentration of the velocities near the Guide Bank with consequent reduction in the attack on the unprotected south bank.

The layout of the guide bank and has had to be further amended to suit the reduced waterway finally adopted for the Bridge (14 spans of 403 feet 4½ inches each instead of 14 spans of 420 feet each in Mr. J. M. Fenton's design). The experiments had been carried out with 5880 feet as length of the (water portion). The upstream sole head has been kept undisturbed in the same position as was in the model experiments, and the curvatures have been slightly altered to meet the new position of pier No. 15 as shown on Plan No. VI. The cross-sections of the massive clossure bund, representing the road formation, railway formation for the main line and formation for the ring bund siding are shown on Plan No. V. Total length of the guide bank along its centre line is about 8185 feet (6728 feet on upstream side and 1457 feet on downstream side of the bridge centre line).

(iii) *South Bank* :—

The effects of floods on the unprotected south bank will be carefully watched, particularly the rate of recession of the firm red clay ledge if any. A proper survey of the clay ledge along south bank is being carried out and will be studied during and after floods every year. A powerful motor launch equipped with an echo sounding apparatus has been arranged to study the effects of floods on deepening of South Channel. It is proposed to lay a railway siding on the south bank connected with the main line for accessibility. The south bank is uneven and rugged having been damaged in the past by erosion and villagers for making bricks, etc. Uneven bank is likely to cause swirls and may cause further damage locally, specially when the total discharge through south channel will be nearly double during flood seasons (North Channel having been scaled). It is proposed to provide a layer of hand packed pitching 2 feet thick along the South Bank above R. L. + 131 for a length of about 6000 feet to present a smooth and even surface for the flood water to glide past without further surface damage to the bank.

RAIL COACH FACTORY DOUBLES SCHEDULED PRODUCTION

During the first year of its production, the Integral Coach Factory at Perambur is expected to turn out twice as many passenger coaches as it was originally scheduled to do. As the full target production of 350 coaches is now expected to be reached earlier than originally proposed, global tenders for additional machinery have been invited. Out of 544 machines which were ordered abroad, 543 have already been received in the Factory, and a majority of these have been erected. The very first machine was installed on January 20, 1955.

The fourth batch of 199 apprentices recruited in November last year for training in various trades has reached the end of its six-month training at the Factory's training school. Selection of the fifth batch has been completed, and training would commence shortly. Last January, a further batch of 14 selected technicians left India for Switzerland to undergo six months' specialised training at the Schlieren firm. As steel supply continues to cause difficulty, action has been taken to expedite the supply of about 5,000 tons of steel section and plates from suppliers abroad.

Front and Trailing Trucks—their Influence on the behaviour of a Locomotive

By M. S. Surma

IN response to the demand of increasing traffic, the power and consequently the size of locomotives is being increased considerably, and the limitations imposed by the moving dimensions, force this increase in the longitudinal direction only. If the locomotives were to move only on the straight tracks, the increase in their length would be beneficial as,

(i) A longer wheel base results in a reduction of angularity in track.

(ii) Full weight of loco can be utilised as adhesive weight and thus slipping of wheels while pulling heavier loads can be avoided.

(iii) The problem of axle load limitations is solved.

But their running on curves and turn-outs brings in the problem of wheel rail infringement which can only be solved, either by the provision of enormous lateral clearances at the intermediate wheels or by dividing the whole locomotive in a number of trucks.

When both of these alternatives are studied, it would be found that it is advisable to divide a locomotive in a number of trucks than to provide sufficient lateral clearances at the inter wheels. In this way not only the required flexibility on curves and turn-outs is provided, a control mechanism can also be located suitably for efficient guidance. Apart from the consideration of running in curves and turn-outs, the use of low grade coals is another factor which necessitates a trailing truck and more preferably a single axle truck.

While dividing a locomotive into different trucks, the following vital points are to be kept in veiw:—

(i) All the axles grouped together under a common chassis should be parallel to each other.

(ii) All the wheels forming a truck should preferably have equal diameters.

(iii) The trucks should be able to swivel and if one of them is unable to swivel, the other should not only be able to swivel but should be capable of lateral movement as well.

In a locomotive the main truck consists of the one formed by the coupled wheels, and the others trucks, if any, are called the auxiliary trucks. The main truck is unable to swivel but is provided with little transverse play, but the auxiliary trucks have provision for lateral movement and swivelling. On Indian Railways they are found in the following combinations :—

(a) Pony at front end.

(b) Pony at front and at rear.

(c) Bogie at front only.

(d) Bogie at front and at rear.

(e) Pony at front and bogie at rear.

(f) Bogie at front and pony at rear.

From the above combinations it will be seen that though the system of providing auxiliary trucks is found in so many combinations, the kinds of trucks are only two namely four wheeled bogies (The bogies, in use in India have four wheels only, though six wheeled bogies are in use abroad) and two wheeled ponies.

The three important points, by which the influence of a bogie or a pony truck on the behaviour of a locomotive can be determined are :—

(i) The location of contact between flange and rail. This contact have three locations. (a) Ahead of the vertical through axle centre. (b) At a point on the vertical through axle centre. (c) And behind the vertical through axle centre. It can be proved by the resolution of forces acting at the point of flange rail contact, that the magnitude of the lateral force which an axle can withstand before it derails is pretty high in the case of trailing contact (when the wheel is said to have an inward running tendency) than in the case of a leading contact (when wheel is said to have outward running tendency).

(ii) The guiding force which a truck can supply through its control mechanism, the optimum value of which should be sufficient to guide a locomotive around a curve or a turn-out with the least possible flange impacts. For the considerations of safety the value of the optimum guiding force has to be kept under a specified value.

(iii) The amount of lateral swing provided for the truck for smooth running around curves and turn-outs. The maximum desirable value of this swing can be determined by plotting the locomotive on the sharpest curve or turn-out it has to negotiate. The swing should be sufficient to avoid any flange rail infringement. Mathematically the swing for a single axle truck, as given in "Steam Locomotive" by R. P. Johnson can be determined by the following formula.

$$S_p = \frac{d.y^2 + y.c.R}{y^2 + R^2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

For a double axle truck,

$$S_b = \sqrt{R^2 + B^2 + A\,B} \quad R \quad \ldots\ldots\ldots (2)$$

Where,

S_p is swing of pony.

S_b is swing of bogie.

A is length of rigid wheel base.

B is distance between the leading coupled wheel and truck pivot pin.

C is distance between the rigid wheel base centre to pony pin.

d is Radius of curve minus lateral clearance at inter wheel.

R is radius of curve.

Y is length or radius bar.

In the light of the above considerations, an attempt has been made in this note, to discuss in a brief and a simple way, the behaviour of different combinations of the auxiliary trucks i. e. bogies and ponies.

PONY TRUCKS

A pony is a single axle truck used in front as well as rear of certain locomotives. While traversing curves it always adopts constrained curving, because of one of its flange being guided by outer rail and of its attachment to the engine through radius bar, which allows it to run radial to the curve, giving it a natural inward running

tendency. The optimum length of the radius bar can be calculated by the well known Baldry formula,

$$Y = \tfrac{1}{2}\,(T - F^2/T) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

or from the formula given in "Steam Locomotive" by Mr. Ralph. P. Johnson,

$$Y = \frac{(A + B)\,B}{A + 2B} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where,

F is ½ the rigid wheel base.

T is distance between the centres of rigid wheel base and pony truck

PONY AS A GUIDING TRUCK

For a given speed, there is a minimum guiding force which must be supplied by the control mechanism located on a pony, to guide a locomotive around a curve. At the same time the value of this guiding force, for consideration of safety, should not exceed certain percentage of the axle load of pony truck. As stated before that the remarkable characteristic of a pony truck is its tendency to run inwardly, thus the flange rail contact being behind the vertical through axle centre and the centre of friction ahead of the axle. If this behaviour of the pony trucks can be guaranteed, they will really be very efficient guiding agents for locomotives but unfortunately a higher value of control force sufficient to guide a modern high speed locomotive round a curve—forces it to adopt an 'outward' running thereby placing a definite limit on control force which can be tolerated in the case of a pony truck.

It may be mentioned that hardly, in India we come across a pony truck having more than 12 tons axle load, and if control force is limited to 40% of its axle load — a fair figure for the safety consideration — then it may be concluded that the figure will be ridiculously small to guide a heavy and high speed locomotive. It proves that a pony truck in the case of a high speed locomotive cannot be considered as an efficient guiding agent.

PONY AS A TRAILING TRUCK

A locomotive while running in a curve requires a minimum possible control force at its rear end as it opposes the locomotive to adopt itself in curve. Though this anticurving force at the rear of a locomotive is undesirable yet a minimum value of it, just capable of making the rear truck self-centring while running out of curves, has to be provided. The value of this force is pretty small as compared with the guiding force at front. Therefore a pony truck which 'misbehaves' under the influence of a heavy control is most suited as rear truck. As it runs radial to the curve it negotiates it does not produce rearing action on the rear of locomotive.

BOGIE AS GUIDING TRUCK

A bogie with two axles is more suitable as a guiding truck as it can supply double the amount of control force than a pony truck. While running on the curves it may run either with its leading outer wheel or with both leading and trailing wheels against outer rail. The latter is advantageous as the reaction of the control is shared by both the flanges and thus the leading wheel of the bogie is relieved of some of the flange force. If the contact with the rail is made by the outer leading wheel only it is sure to have an outward running tendency so that the wheel cannot take up sufficiently heavy lateral loads and its tendency always will be to mount the rail. If both the leading and the trailing flanges make contact with the outer rail the bogie becomes inward running and the wheel in this case will be able to withstand heavier lateral loads without any danger of derailment. The inward running tendency for the bogies can be gained by providing the swivelling arrangements about the pivot and the control mechanism within the wheel base of the bogie.

BOGIE AS TRAILING TRUCK

When the bogie is trailing it helps the engine to turn itself and adjust in the track while running on the curves, but is unable of turning itself. This induces a rearing action. It is bound to run 'outward' and its leading wheel will always be binding on the outer rail making contact with the rail ahead of the vertical drawn through the axle centre. It also produces some anti-curving effect on the engine as it is well known that any

appreciable control force in the rear will resist the efforts of a locomotive to screw round the curves.

BOGIE AT THE FRONT AND AT REAR

In this case if the locomotive is to run only in one direction, the action of the leading bogie is to guide the loco round the curve smoothly, if provided with adequate control, but as stated above the presence of the trailing bogie will produce rearing action. If the locomotive is to run in both the directions, the problem becomes of a different nature.

As is well known that leading bogie with adequate control helps in guiding the locomotive on curves and a trailing bogie gives an anti-curving force, therefore the amount of control at the rear should be as little as possible, say, only to overcome the friction between the slides of the trailing truck, so that the engine is forced back to its central position after curving out. Even if this control is slightly less than the friction between the slides, it will bring the engine back to the central position, as the frictional resistance between the slides is always changing on account of the vertical oscillations at the cab end.

If the locomotive is to run in the backward direction, this bogie which has a very little amount of control will be leading, and it will be impossible for it to guide the locomotive round the curve without the danger of derailment and excessive lateral forces on coupled wheels. In this case the maximum guiding will be done by the leading coupled wheels. But at this wheel has a smaller lever arm about the centre of friction, it will be subjected to comparatively greater lateral forces. At the same time the trailing bogie with a heavier control will hardly allow the locomotive to screw itself round the curves. The danger of derailment, therefore, in this case is far greater.

If the locomotives fitted with trailing bogies are to run in one direction only, the control provided should, be as stated before, very little. The locomotive while running on a curve does not run as a chord to the curve but facing outward so that the centre of friction always is somewhere between the trailing coupled of wheel and the trailing truck, and the value of the control will not go so high as to be very detrimental.

To provide adequate guiding for the high speed locomotives, the best combinations, therefore, seem to be a bogie at the front and a pony at the rear.

END CONTROL

Controls, if adequate at the front at the rear of a locomotive, will not only keep the whole locomotive in a single rigid wheel base on a straight track, thus making it run 'hunting free', but will make it run smoothly round curves without giving rise to excessive flange forces. If the curve around which a locomotive has to pass is without any irregularity, then with adequate control force, the whole guiding will be performed by the front truck, without the locomotive encroaching upon its lateral clearances on coupled wheels. But as the irregularities in the track cannot be avoided the function of the controls remains to reduce the value of flange impacts to minimum possible.

Controls may be divided into two classes, viz.

(i) Gravity control and
(ii) Spring control

GRAVITY CONTROL

Gravity controls are provided by the introduction of either slanting slides, for example Cartaxi slides, or swing links. In the case of slanting slides, the locomotive after getting shifted from the central position, will try to come back to the original position under the action of gravity. The presence of the slanting slides affects the weight distribution, which is undesirable and therefore they have almost been eliminated as control agents. In the case of swing links if the locomotive drifts from the central position, the vertical component of the link tension and the compression on the spring, force it to come back to the central position. The wear on the pins in the case of a swing link cannot be avoided and consequently the value of the control is affected. On our new locomotives the swing link control has been replaced by more efficient one i. e. spring control in conjunction with slides.

SPRING CONTROL

Two types of springs—laminate or helical—are used in this system. The laminated springs when used afford damping on account of the friction between the plates. This friction has a detrimental effect of reducing the force by which the locomotive has to be forced back to the central position after moving out of a curve, because some work has to be done to overcome the friction between the slides. Sometimes on account of this friction the instantaneous force of the laminated spring becomes less than the frictional resistance between the slides and the truck, even after leaving the curve, goes on running towards one side till such time due to vibrations the frictional resistance between slides reduces to an extent that the spring force is able to move the slide laterally to the central position. Therefore, if the laminated springs are used as control springs, there initial crack off will have to be kept sufficiently high to cope up with the above mentioned phenomenon. As the total initial crack off has to set at a specified limit, laminated springs can only be used where metal slides with efficient lubrication are used.

A difficulty, in the case where metal slides with lubrication are used, is generally experienced to attain efficient lubrication. Experience has shown that it is impossible to avoid dirt finding its way thus causing the friction to attain a very abnormal value which may sometime cause a derailment.

In view of the above argument, it may be concluded that laminated springs and lubricated metal slides cannot efficiently perform the function of control device and therefore, they are not very suitable.

It may be mentioned that the two XP locomotives, when first came to India, were fitted with the laminated spring controls. The location of the control at the front end was as usual, but for the rear end it was at the front tender bogie instead of at hind truck. The location of the rear control was however, again brought to the hind truck and the laminated springs control were replaced by helical spring controls, and lubricated metal slides were replaced by fabric friction material slides.

HELICAL SPRING CONTROL

The helical springs do not offer any damping effect and unlike laminated springs do not loose any force while attaining there original position. When these springs are used in conjunction with the friction material slides with a low coefficient of friction say 0.15 or even lower just to offer sufficient damping, give really very good results. The friction slides are meant to run dry, therefore there is no trouble of maintaining the lubrication. They are supposed to have a constant coefficient of friction throughout the service, if given a good smooth surface before fitting in position. Care should be taken that these slides are not lubricated and that the engines fitted with these slides are not allowed to stay idle for a considerable period otherwise there is a danger of these slides getting jammed.

Research on the Indian Railways is in progress to find out a suitable material to match with these slides which will give the lowest and a constant coefficient of friction. Trials by the Research directorate have also been conducted, to determine the behaviour of guiding tracks, when these slides have a reduced bearing area. Some interesting results will come out when the reports of these trials which are under preparation are published.

ANTI-SWIVEL CONTROL AT THE BOGIE TABLE

Moderate friction at the bogie table is desirable to oppose any independent nosing of bogie trucks under a locomotive. At the same time friction should not attain a value so as to augment flange loads at the leading bogie wheel. Mr. da Costa in his paper "Riding of Pacific Locos" has worked out an example which gives the limit for the moment of this frictional couple for a bogie with a particular wheel base and vertical loads on its axles.

EFFECT OF THE AMOUNT OF CONTROL

If the control on the front end of an engine is increased it relieves the leading coupled wheel of the flange force but brings an increase on the truck wheel flange force. This has an advantage, because if the wear on leading coupled wheels on account of excessive flange force is greater, and if the leading coupled wheels are to be turned down to the correct profile, all the coupled wheels, irrespective of the amount of wear on them, will have to be turned so as to have equal diameters. A comparatively greater amount of work, time and money will be involved. But if by the provision of a heavier control, the wear on the leading truck wheels, is greater, necessitating the turning of these wheels, it will be comparatively an easier process.

A very heavy control at the front end makes the leading truck to bear the brunt of the guiding force. On its being at the extreme end, if on account of excessive lateral force it derails, the total guiding will then have to be performed by the leading coupled wheel—only a relatively small share being taken by the other wheels—which are nearer to the centre of gravity of the locomotive. Leading coupled having relatively smaller leverage than that of the front truck may not be able to guide the locomotive effectively and under the influence of heavy lateral forces may follow the leading truck with disastrous consequences. If perchance the wheel, in the case of weaker front control, derails, the leading truck because of its greater leverage can still guide the locomotive and there is a possibility of the leading coupled again getting on to the rails as in fact has been once noticed at Weaver Junction in England.

THE AMOUNT OF CONTROL FOR EFFICIENT GUIDING

The amount of controls at the ends of a locomotive is so determined that the locomotive may remain in a single rigid wheel base while running on straights and may pass the curves with the slightest possible flange loads. At the front end its value is fixed by taking moments about the imaginary centre of friction at the wheel treads of all the coupled wheels and then by balancing the sum of these moments by another moment about the same centre of friction at the front truck. For example consider a locomotive as in fig. No. 2. The centre of friction is assumed to be at the hind truck. Then the moments will be,

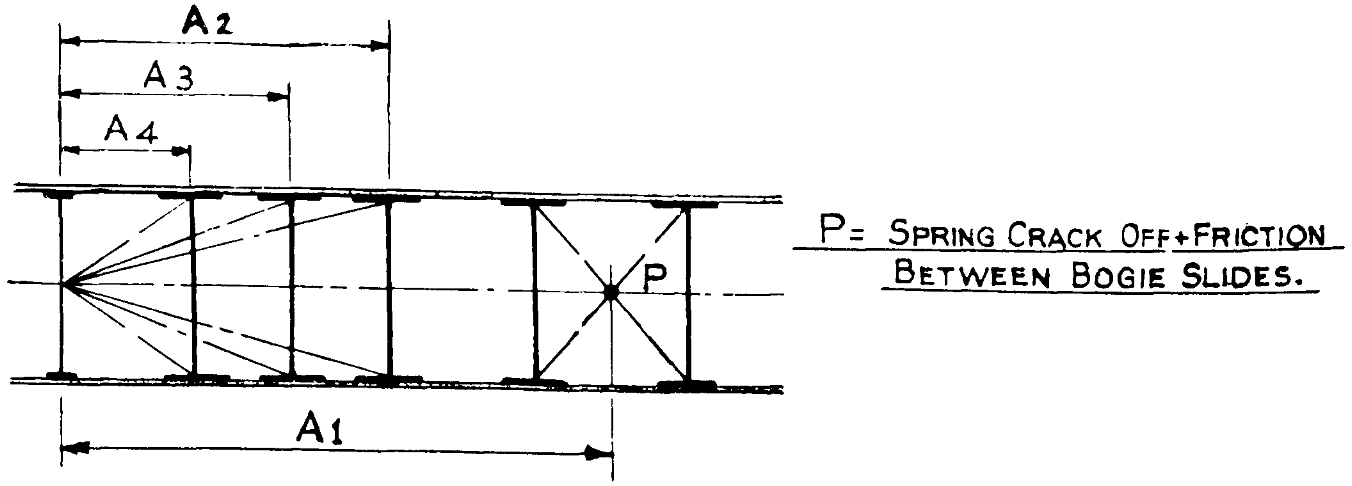


Fig. No. 2

$$2UW\sqrt{A_2^2+G^2} + 2UW\sqrt{A_3^2+G^2} + 2UW\sqrt{A_4^2+G^2} \quad ..(5)$$

Consider this equal to K

This moment should be balanced by the moment of the coupled $A_1 P$ ....(6)

From which,

$$P = K A_1 \quad ....(7)$$

where,

W = Wheel load,

= Coefficient of friction between wheel and rail,

$G = \frac{1}{2}$ the track gauge at the tread contact points and

A_1 A_2 A_3 A_4 as given in Fig. No. 2.

The value of P thus arrived at is equal to initial spring crack off plus frictional resistance between the truck slides. The distribution of the load P between the spring crack off and the slide friction is proportioned in such a way as to keep the initial spring crack off a little higher than the frictional resistance between the slides. The maximum value of P may be limited to 40% of the load under the truck.

After a considerable research, the Indian Railway authorities have set out the optimum values of controls at both ends of locomotives. The initial control at the front end may be 16% of the truck weight on the rails with the control spring deflection of approximately one inch for every 20% of the truck weight on rails. To this will be added the frictional resistance of the slides. The amount of control at the rear end may be set at 20% of the truck weight on rails but with a sufficiently greater deflection of the spring per ton load.

RAILWAY DELEGATION TO CHINA AND JAPAN

A three-member Railway delegation left New Delhi on Saturday 9th June, 1956 for a month's study tour of the Railway Systems of China and Japan. The members of the delegation are Shri J. Dayal, Financial Commissioner for Railways, Shri K.B. Mathur, Member (Transportation) Railway Board and Shri H. D. Awasty, Joint Director (Planning), Railway Board. The delegation is expected to tour important Railway sections in these two countries and, in particular, make a detailed study of the working of important marshalling yards and control offices; regulation of movement of traffic; the working of the centralised traffic control system; the capacity of single line sections by diesel and by electric traction; operation of heavy mineral traffic like coal, iron ore etc., and compilation of statistics. The delegation will stay in each country for about a fortnight.

FRENCH RAILWAY ENGINEERING NEWS

SOME FACTS ABOUT THE CC 7107 LOCOMOTIVE

IT is remembered that the CC 7107—1500 v — 107 f — 5000 Hp. locomotive has reached on March 28, 1955 the speed of 206 mph.

Due to the special equipment designed by the French National Railways, it has been possible to study the behaviour of locomotives on tracks of various types.

This equipment has permitted to measure the lateral and vertical stresses applied to the rails by the wheels of the locomotives.

Made over a period of more than 15 years, these tests led to a theory of the stability of rolling stock.

It was, however, essential to make tests in conditions far in excess of those encountered in normal working so as to be able to prove the sound basis of established theories and thus to determine the actual margins of safety of the various parts.

Four Alsthom type CC locomotives of the 7100 series of the French National Railways had already exceeded several times a speed of 124 mph.

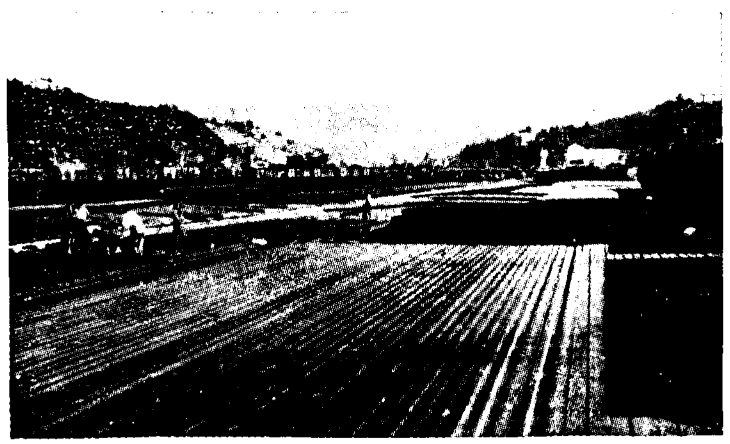
In February 1954, the locomotive 7121 reached a speed of 151 mph. without any special preparation.

This speed was however limited in practice by the speed of rotation of the traction motors and the curves of the track, and not by the locomotive itself.

The French National Railways carried out these tests on two types of locomotives of different design, one of which was the Alsthom CC locomotive No. 7107, also of the 7100 series.

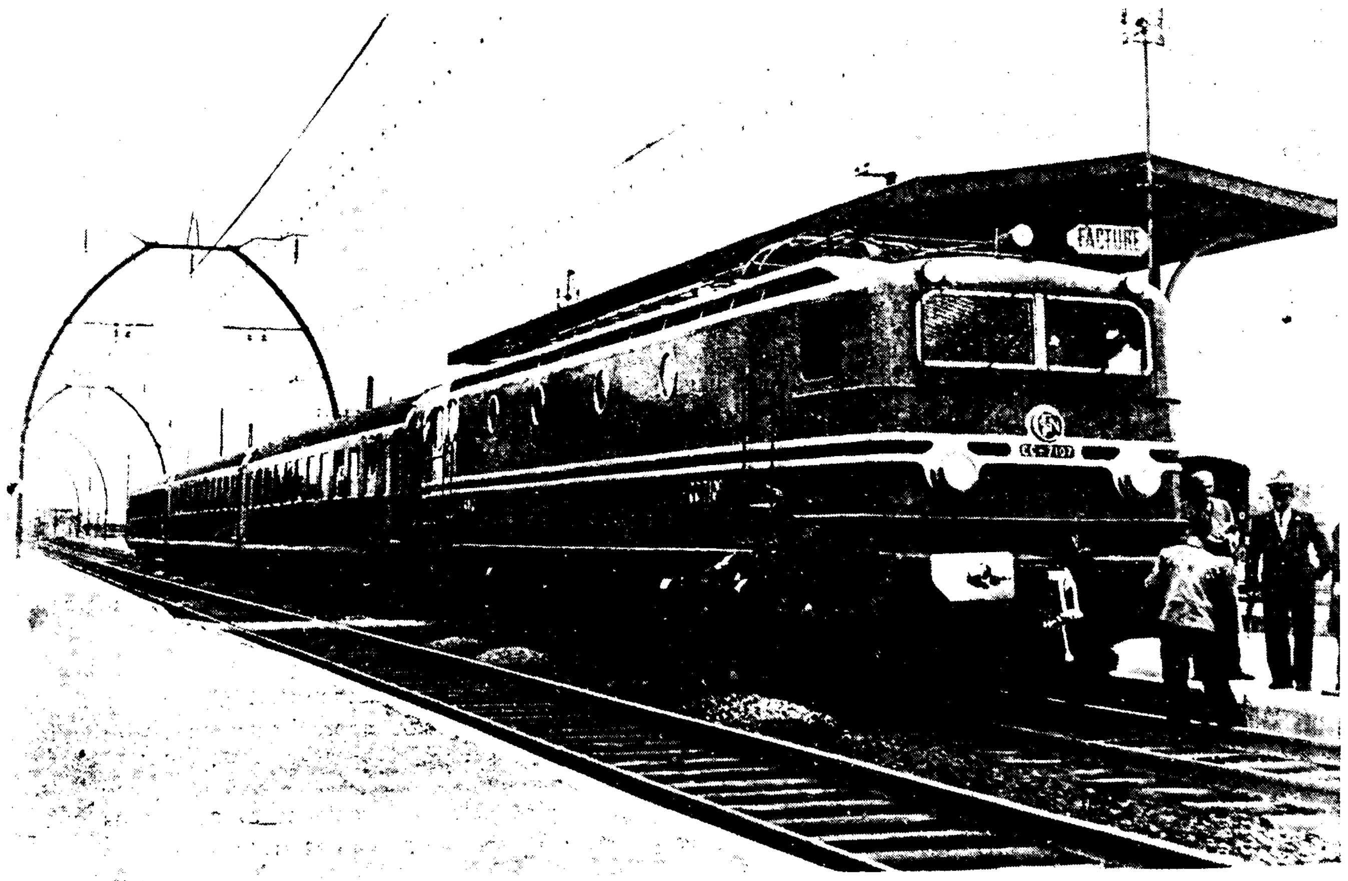
Only the gear ratio was modified and slight aerodynamic improvements were effected.

The power absorbed, however, exceeded 12,000 HP., which is of the order of three times, the normal power rating.



Important welding yard—Set Spot.

Welding in tracks.



This CC 7107—1500 V. 107 f, 5000 HP. locomotive has reached on March 28, 1955 the speed of 206 mph.

Built by Alsthom Cy. this machine is characterized by its perfect stability, its reduction in fatigue stresses on the track as well as in wear and maintenance, its robust construction of the mechanical and electrical parts. and its ease and economy in maintenance.

At the highest speeds, the stability of the CC locomotive proved very satisfactory. The lateral stresses recorded during the tests were exceedingly small, and thus the quality of the design of machines of this type and their high degree of safety in operation were proved beyond any possibility of doubt.

The "CC" locomotive possesses main advantages :

—High speed, total adhesion locomotives.

—Important adhesive weight enabling, to haul heavy trains.

—Axle load less than 18 tons which makes it possible to use them on all lines.

In addition, by virtue of a number of original devices, amongst which may be cited : bogies with double pivot, axle boxes, with internal take-up, guiding of axle boxes by means of articulated links, general use of rubber and manganese steel for articulations, eliminating wear and the necessity for greasing, there is obtained :

—Perfect stability,

—Reduction in fatigue stresses on the track as well as in wear and maintenance,

—Robust construction of the mechanical and electrical parts,

—Ease and economy in maintenance.

As a result of all these advantages, Alsthom have received, since the putting into service by the French National Railways in 1949 of the two prototype locomotives 7001 and 7002, repetitive orders giving a total of :

—60 locomotives 107 tons — 5000 HP. 1500 V for the French National Railways. The first have already travelled a distance of nearly

—932,000 m. and a large number more than 310,686 m. One of them has run over 372,823 miles without general overhaul.

(Continued on page 70)

The French Thomas steel rail—Rail Inspection, Utilisation and Service Behaviour

By M. Palme,
Chief Engineer for Rails in the French National Railways. (S.N.C.F.)

THE Western European countries and particularly France stand in a rather particular position as far as rails are concerned. As a matter of fact, the quality of the iron ores available and the industrial equipment of many of their Iron and Steel Plants have led to make us, regarding rail manufacturing, of the basic converter (Thomas).

On the other hand, the importance of the industry and its geographical situation have resulted in a very dense railroad traffic and, as a consequence, rails must be of a very high standard.

It has therefore appeared interesting to investigate how this problem had been solved in France.

SOME DATA ON THE SNCF SYSTEM

By its length of tracks, the French system is one of the most important: 25,215 miles; consequently it is materially longer than the biggest U.S.R.R. systems (Santa Fe' and Pennsylvania systems) and also than the British Railways network (19,262 miles).

The French R. R. traffic can also favourably compare with those of the biggest foreign R.R. systems.

Supposing that the French system total traffic is to be estimated in unit-kilometers (viz. passenger-kilometers + ton-kilometers), it shows that it exceeds Santa Fe's. From the carried Freight standpoint it nevertheless is inferior to Pennsylvania which serves on the American continent the most important regions from the economic point of view. There are however in France many lines with heavy traffic: the Charleville-Thionville trunk-line has, for instance, a daily freight traffic of approx. 80,000 m. tons (45,000 m. tons one way; 35,000 m. tons the other).

This traffic is largely supported by cars with 18 to 20 tons capacity per axle and at speeds ranging from 37.28 miles) to 46.60 miles an hour (above axle loads are of the same importance as those of certain engines). In addition to this, the French R. R. Cy's so that finally the French R. R. traffic approximates that of the biggest U.S. R.R. system.

Engine axle loads amount to 21 m. tons on steam engines, type 242 A1 and 22 m. tons on electric engines; type 2D2. On the other hand, in the CC high speed type electric engines, this load has been reduced down to 17 m. tons.

Now, here are some information about the powers developed by these engines:

The 242 A1 type steam engines have 5,000 CV (4931 HP.) power and are the most powerful in Europe.

Regarding the electric engines, their powers are still greater (5,326 HP. when based on a one hour operation, 4,830 HP. in normal continuous working conditions) in the 2D2 engines assigned to fast trains. CC engine features are of the same importance (5,370 HP./one hour operation, 4,418 HP. in normal continuous working conditions); it holds the World speed record. To note that many R. R. lines have been electrified on account of the importance of that type of energy available in France. Electrified lines amount to 10% of the RR system track length (2,672 miles) and bear 30% of the traffic.

These engine powers together with track maintenance high standards have made possible to run trains at high speeds: standard type trains reach 87 miles an hour.

To mention for instance, the Paris-Lyons run (318 miles) in 4.10 hours, viz.; a commercial average speed of 76–428 miles[1] and the Paris-Bordeaux one (361 miles) in 5.10 hours, viz. 69–59 miles an hour, average speed.

(1) It constitutes the highest commercial speed record on a 310.685 miles run. On such distance the fastest US train seems to be the "City of Los Angeles" which averages 72.116 miles. Furthermore USA and France are presently the only countries in the extra high speed category.

The World speed record was fallen in February 1954 by the CC engine No. 7121 when it reached 150–993 miles an hour and it was again beaten when upped to 205–052 miles an hour by two electric engines, a standard model "CC", the CC 7107 and the "BB" type No. 9004. The engines were entirely French engineered and the rail tracks were fitted with Thomas steel (101 lbs./yd.) rails.

In short, the French RR system has to cope with an important traffic, wherein must be included a strong proportion of heavy axleload cars, and the spedes are

(Continued from page 69)

—80 locomotives of which 60 are built in Spain (120 tons, 3400 HP. 3,000 V) for the Red National de los Ferrocarriles Espanoles.

—15 locomotives 111 tons - 4,650 HP. 1500 V for the Nederlandsche Spporwegen.

" THE FRENCH RAILWAYS ARE FAR AHEAD OF OUR OWN "

During the course of an interview, Sir Brian Robertson, Chairman of the British Transport Commission, admitted that the French railways were well ahead of the British railways.

" .. Having received an invitation from the French Railways, I decided to go and study their system on the spot. There is no doubt that the French Railways have a long lead over us. They are well ahead of us in the matter of modernisation and punctuality and the reason for this is that they have spent much more than we have since the war ".

COMPAGNIE DES ATELIERS ET FORGES DE LA LOIRE

It is interesting to reveal that the first 700 HP. Diesel electric locomotive, manufactured by the Compagnie des Ateliers et Forges de la Loire in its Sain-Chamond plant, has been delivered to Reseau des Chemins de Fer de la Mediterranee au Niger (Mediterranean Sea to Nigeria Railways) on April 30th, 1956.

high, both for passengers trains and for freight ones as well.

THE THOMAS STEEL RAIL[2]

It is evident that, in order to withstand such a traffic, the rails must be of high quality for economical reasons and for safety ones too—Safety is known as first and number one concern of the RR engineer – There can't therefore be any motive allowing the use of poor quality rails.

The part that a rail must assume is multipurpose; it forms simultaneously a beam and a runway. It must, moreover, be easily weldable. And finally, for reasons of safety, it must have an excellent impact resistance.

All these conflicting characteristics are so much the more uneasy to combine that the rail must also remain a relatively cheap item, thus limiting the choice in the possible solutions from the metallurgical viewpoint. It means that the rail, in a modern RR system, remains an item on which researching never ceases, by track and steel Engineers, and that nothing which pertains to this field can be left to chance. It constitutes finally a key-product and that is the reason why all questions pertaining to the Thomas steel rail deserve investigation.

TECHNICAL SPECIFICATIONS

The French Standard Specification (Technical specification 523) which was in the use up to April 1954, gave much importance to the physical tests. Chemical analyses were performed only for information. It was then considered that the purpose to be fulfilled was only the results given by the mechanical tests and that the conditions for this end, principally steel analysis, were to be left to the supplier's decision. But on the other hand, conditions regarding steel homogeneity and impact resistance were very exacting. It was the reason why a macrographic inspection, together with a very special impact test (notched bar test) had been specified. Said test is very severe and it has been observed that some imported rails produced from heats which had successfully undergone tests provided by some foreign specifications, could not very often stand the notched-bar one.

Also to be noted that the quantity of test was materially stronger and that size tolerances were stricter than provided by most foreign specification.

STANDARDIZATION OF THE TECHNICAL SPECIFICATIONS COVERING RAIL SUPPLIES

Under the supervision of the International RR Association International Standard specification was prepared for rail supplies and came into force in April 1954.

The main departure of the new International Standard Specification from the former French one concerns the impact test applied on unnotched test-pieces[3]. The macrographic examination has been maintained. A fact which is worthy to note is that no differentiation has been established between Siemens-Martin, Thomas and Bessemer Steels, except regarding analyses and tensile strengths.

FRENCH RAIL SECTIONS AND WEIGHTS

The standardized French sections are of the following weights 90, 101, 111 lbs./yd.

The 90 and 101 lbs./yd. profiles are used for standard tracks and the thick web 111 lbs./yd. profile is exclusively used under tunnels.

The new sections, presently investigated by the U.I.C. (111 and 121 lbs./yd) with a view to standardization of the European rail, offer a sensible balance between the flange and the head masses so as to make away with cambers occurring during colling and consequently reduce straightening operations to a minimum.

This improvement of the section masses distribution also presents the advantage of increasing the moment of inertia.

BOND HOLE DIMENSIONS

Bond hole drilling is one of the critical operations in rail manufacture: it is within this area that an important percentage of deteriorations and fractures show up under operational stresses. Numerous and various tests have proved that a reduction of bond hole I. D., even slight, would very much improve resistance to crack formation. These are the reasons why the I. D. has been reduced from 1 17/64" to 29/32". Thanks to this measure bond hole cracks have become much less frequent.

RAIL BAR LENGTHS

Rails are generally 59' long since this size has proven as being the most propitious to their life time.

(2) To note also that Belgium and Germany, both being countries with an important heavy industrial activity, therefore with an intense RR traffic, also make use of Thomas steel.

(3) The U.I.C. is, on the other hand, preparing presently an impact test on notched test-piece with simultaneous recording of the fracture energy.

WELDED LONG RAILS

Presence of joints in a track rail undoubtedly constitutes a heavy maintenance servitude and rail joint conditions are in fact the main life factor. The SNCF have thus been led to use long rails assembled by welding[4]. Up to now, 994—193 miles on trunk lines of various importance are of the welded type and the future programs have provided for an extension of the procedure (497, 086 miles in 1955). Special expansion devices take up rail expansion.

Of course the disappearance of the conventional joint further to the advent of the welding process has only been made possible by using rail fastenings capable of elasticity allowing for a constant rail sleeper cohesion.

In this type of track rails, new extra stresses due to contraction of the steel in cold weather, add to the normal operational stresses which are thus doubled: to withstand such conditions the rail must be without any surface defects, and especially so regarding the flange. It is particularly interesting to acknowledge that the French Thomas steel rails, produced by the "V" shape cutting of the bloom have offered excellent results under those conditions.

RAIL WELDING

The procedures are employed:

(1) The electric flash welding, performed in specialized workshops with automatic equipments. Thousands of such weldments are made every year.

(2) The thermit welding process, is on the contrary made on the site. It has been very much improved and simplified these last twenty years and it is widely used on account of the ease with which it is applied.

These methods have made possible the re-utilisation of old rails, after being cut to new dimensions and welded, and also to join with excellent results wear-rails or different rail profiles together. Generally 236' to 945' lengths are shop welded, to be further on assembled together on the site in tracks by the "thermit" process.

From this very short survey can be drawn the conclusion that the welding techniques have now been well perfected and that the rail steel used is perfectly weldable, whatever the process.

RAIL DEFECTS

Rails can show various defects, almost identical in all RR systems of the world. The most common ones or the most dangerous ones shall be examined hereunder and indications shall be given as to the precautions taken in France to cope with them.

Fractures in bond hole zone: Recurrence of this kind of fracture has already been brought down by substituting the 29/32" to the 1 17/64" I. D. hole. An additional improvement was supplied by a milling of the bond holes—after rolling—by mean of a special milling drill.

As an example, a plant which has been the last fifteen years manufacturing by this process approximately 60,000 m. tons has up to now recorded only two fractures in the bond-hole zone, circumstances constituting excellent results. The welded long rail represents an other complete cure against this kind of failure.

Internal transverse cracks: This defect, a serious one since several fractures may happen simultaneously within the rail, is to be found more frequently in Siemens-Martin quality rails than in the Thomas quality ones.

In order to take every precaution to prevent what could be resulting from this kind of failure, we have nevertheless started to make use of a mobile testing equipment (using electromagnetic and supersonic methods) and with which is proceeded to a systematical check of those tracks coping with the heaviest traffics. During the two year's check carried out, the average of transverse cracks thus detected was of one per 8.07 miles. This figure is substantially lower than the one found in the US.RR which is about 1 crack every 3-4 miles.

Rail head down squeeze: In French tracks this phenomenon is to be observed principally at rail end joints. Several hardening processes of rail ends have consequently been investigated, all of them consisting in hardening the rail, either in the shop or on the site, with fluids such as water, compressed air, etc.

An induction heating device for rail end hardening is also in use.

Reshaping of worn end rail heads is also practised by electric welding.

Fractures and failures originated by segregation have practical disappeared since standard specifications have provided for macrographic tests.

Just as a reminder, let also be mentioned the flange length-wise cracks liable to turn into transverse

(4) Sometimes 79'

fracture, now seldom to be met with since the new "V" cutting pass of the bloom has been adopted.

As it can be realized, serious efforts have been devoted to the question, which have permitted to eliminate almost all the main types of failures.

STATISTICAL RESULTS

The French figures derive from the official statistics we send every year to the Public Works and Transport Ministry. They show, for 1953, 3.8 fractures per milliard of ton kilometers.

Regarding foreign figures are to be found for the above referenced period when they were issued:

Great-Britain: (2.5 to 5.92—average 4.2)

Germany: 5.8

Belgium: 9 to 10

The average figure in 1939, just after the creation of the SNCF, was for France 6.2. When this figure is compared to the present one of 3.8, it stresses out the importance of the developments achieved thanks to improvements of maintenance methods and also to the metallurgical factors.

Presently, as far as can be known in the absence of official statistics, we are of the opinion that France can favourably compare with the best European RR systems.

PRESENT TRENDS

Regarding rail section profiles, there is a trend towards adoption of a better balanced profile. As already stated above, an European Standardization of rail profiles is under way; it is also to be added that investigations of this kind, by the SNCF, increasingly call for scientific methods and that we proceed to inspections on the tracks with the help of strain gauges, piezoelectric quartz devices, and crackling or photoelastic varnishes.

Regarding the quality of steel, constant improvements have been realized these last twenty years under the instance of the Joint Commission for rails established in 1925. This commission, composed of SNCF engineers and rail manufacturers, to which joined recently representatives from the very important IRSID (Research Institute for the Iron and Steel Industry), investigates the problems arising from rail manufacturing, and, at its disposal the laboratories of the various Members of the Commission, especially the SNCF rail laboratory together with the remarkable IRSID laboratory at Saint-Germain-en-Laye, which constitutes the most complete research combination to be found in France towards metal researching.

PROGRESS OF RAILWAYS—SELF-SUFFICIENCY TO BE ACHIEVED SOON

"SELF-SUFFICIENCY as far as Indian Railways were concerned was now only a matter of time", said Shri M. Ganapati, General Manager, Western Railway at a Dinner Meeting of the Bombay Suburban (West) Rotary Club at Santa Cruz last month.

Shri Ganapati gave a detailed account of the progress made by Indian Railways during the past eight years in the manufacture of locomotives, coaches, wagons and spare parts required. To achieve self-sufficiency, the Chittaranjan Locomotive Works for the manufacture of broad gauge locomotives, costing Rs. 15 crores, and the Integral Coach Factory at Perambur for the manufacture of 350 broad gauge coaches a year, were established. Two other projects, one for the manufacture of locomotives near Banaras, and the other for the manufacture of metre gauge coaches near Bareilly, had been commenced.

In regard to other material like engineering equipment, electrical equipment and heavy machinery for workshops, Shri Ganapati said that the Government was considering the recommendations of the Railway Equipment Committee which had recently submitted its report.

Comparing the large net-work of Indian Railways system to other Railways in the world, Shri Ganapati then stated that Indian Railways were the second largest in the world, the first being the USSR Railways. Among the railway systems in Asia, the Indian Railways were the largest, the Chinese and Japanese Railways being second and third in point of route mileage. Nevertheless, compared to a country like United States of America, which had a route mileage of 2,24,816, our Railways' system paled into insignificance. In spite of our low ratio of mileage, the transport work done by the Indian Railways as measured by the passengers carried, passenger miles, freight tons moved, and freight ton miles effected, was comparatively high and was second only to the Japanese Railways from this point of view.

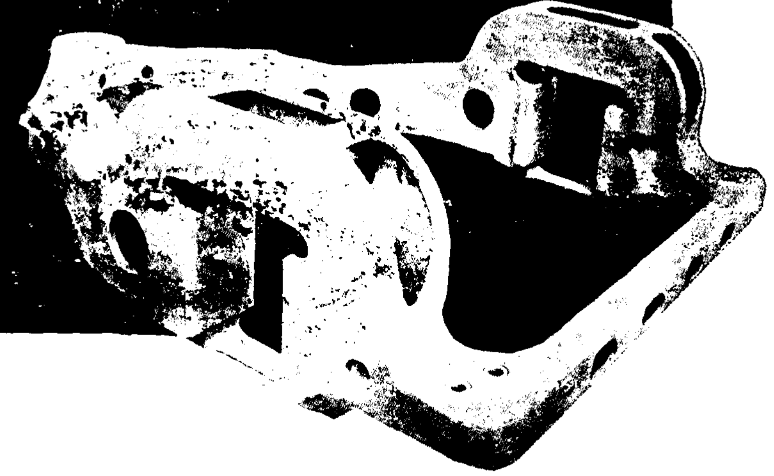
Referring to the First Plan, the General Manager said that against the first plan allotment of Rs. 400 crores to the Railways, the actual expenditure was likely to be about Rs. 432 crores, of which rolling stock accounted for over Rs. 240 crores, covering the purchase of about 1589 locomotives, 4837 coaches and 61,773 wagons both for purposes of additional stock and replacement of old stock. All the branch lines dismantled during the war and recommended for restoration by the Central Board of Transport had been restored and reopened to traffic. 337 locomotives had been manufactured during the Plan period by Chittaranjan Locomotive Works against the target schedule figure of 268, indicating an improvement of 25 per cent over the target. The Ganga Bridge Project started on 26th February 1956, was also making rapid progress. During the plan period, the Railway Workshops, Hindustan Aircraft Factory and manufacturers in the private sector would have produced about 3,400, 7,600 and 230 coaches respectively. As regards wagons, manufacturers in the private sector would have completed 41,200 goods wagons. The annual indigenous building capacity of wagons had been raised to 15,000 units during the end of the first Plan.

In spite of the enormous progress made during the First Five year-Plan, the General Manager revealed, the Railways had still a big leeway to make in overtaking arrears and in replacement of old rolling stock. Despite of all these handicaps, the Railways had carried over 115 million tons of goods traffic at the end of the Plan period, representing an increase of 25% over the year preceding the plan—1950-51. This record performance had been possible not merely due to the small additional stock but due to the more intensive usage of the existing stock.

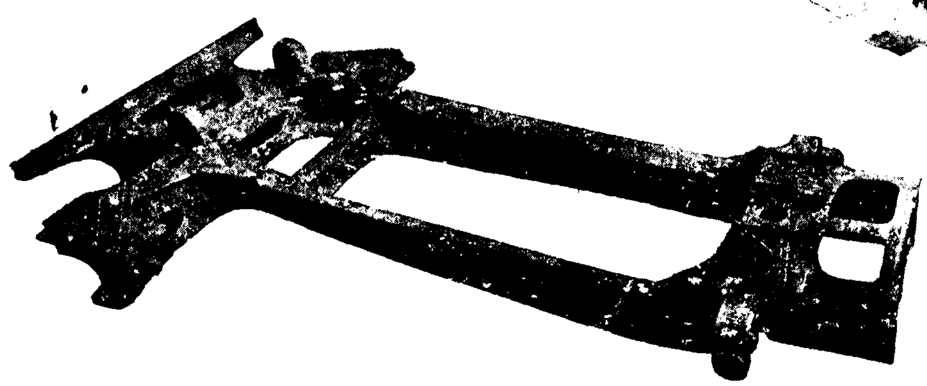
Speaking regarding the Second Five Years Plan, the General Manager drew attention that with the reduced allotment of Rs. 1,125 crores, of which Rs. 375/- crores would have to be found by the Railways themselves from their own revenue, it would only be possible to provide for an additional transport capacity of 15% for passenger traffic and of about 40 million tons goods instead of 60 million tons anticipated.

Of the Rs. 1,125 crores allotted to Railways, Shri Ganapati revealed that Rs. 380 crores would be spent on the procurement of rolling stock, about Rs. 66 crores on the construction of new lines, Rs. 100 crores on the renewal and strengthening of track, Rs. 160 crores on line capacity works and Rs. 65 crores for the remodelling of workshops and setting up of new line to deal with the increased rolling stock. About 850 miles of track were also expected to be electrified at an expenditure of Rs. 80 crores.

Shri Ganapati pointed out that an intensive drive would be launched during the Second Plan period to step up the efficiency of railway working with a view to bridging the gap between the resources available and the capacity needed for moving the anticipated increase in traffic, both in passenger and goods.



Cast Steel 2-Wheel Delta Trailing Bogie Frame



Cast Steel Locomot've Cradle

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