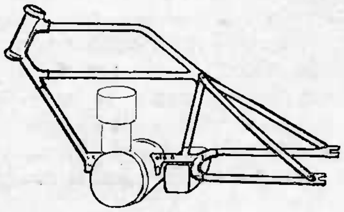
MOTORCYCLE ENGINEERING—6

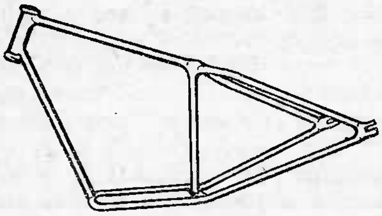
THE FRAME

Second part of a discussion upon the central stress-bearing structure

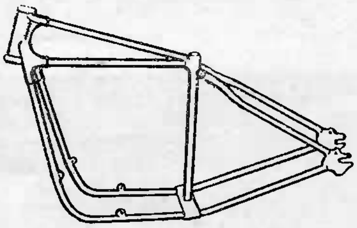
By PHIL IRVING



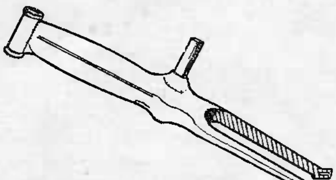
DIAMOND



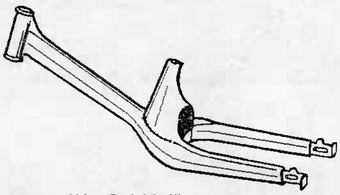
CRADLE



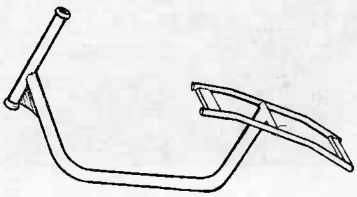
DUPLEX CRADLE



BASIC BEAM



BEAM (NSU "Quickly")



BASIC SCOOTER

SIMPLEST of the many structures developed in the days when frames without rear springing were in general use was the "diamond" type, in which the engine formed one of the members. Despite its lack of triangulation, this could be made to give good handling for a very low weight if due attention were given to maintaining strength at the corners.

A variant of this was the "loop" type, with the down-tube continued in one sweep under the crankcase and up to the saddle; the gearbox, if used, was usually mounted abaft this tube on a lug to which the chain-stays were attached, and the frame was inclined to be narrow and weak in the region of this lug. Additional strength was sometimes gained by adding a second pair of tubes, called torque stays, running from the rear fork-ends to the lowest point of the crankcase, and these did have the effect of steadying the engine against its own torque reaction as well as tending to prevent the frame from bowing under the influence of transmission stresses.

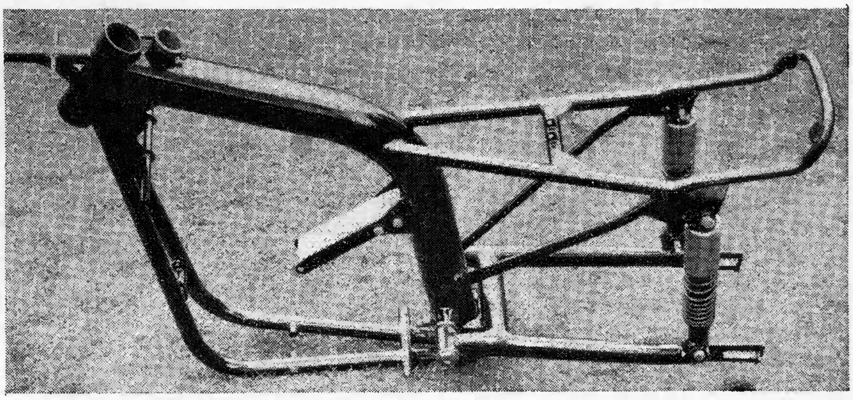
Looked at in plan view, both primary and secondary chains are offset by several inches from the frame centre-line and thus lie well outside the plane of greatest stiffness; consequently there is a strong tendency to bend the frame when power is being transmitted.

Assuming a single-cylinder engine developing, say, 20 b.h.p., and a mean torque of 24 lb./ft., the average pull in the front chain with a normal-sized sprocket would be 112 lb.; but allowing for cyclic irregularity due to the widely spaced power impulses, the *maximum* pull would be around 450 lb., acting at a distance of, say, 4 in. from the centre line. If the distance between engine and clutch shaft is 10 in., the lateral force tending to bend the frame between these points is 4/10ths of 450, or 180 lb.

This by-no-means-negligible figure may be nearly equalled by that resulting from the rear chain pull, because in bottom gear, with a box reduction-ratio of, say, 3 to 1, the mean rear chain pull is increased to 336 lb. (assuming that the engine and final-drive sprockets are the same pitch diameter), but the maximum pull might well be several times this figure during a violent clutch start when the energy of the rotating parts is being absorbed. A figure of around 500 lb. in this instance might be taken as reasonable for calculation purposes. With a chain-line distance of 2¾ in. and 18 in. from clutch to wheel centre, the bowing force works out at 78 lb., so that the total lateral force comes to nearly 260 lb. even with an engine of quite modest power development.

Under stresses of this order, a weak frame must bend to some extent, and as the loads are not steady, but fluctuate in unison with the firing impulses, there is a possibility that they may come into resonance with the natural period of vibration of some component, either of the frame itself or attached

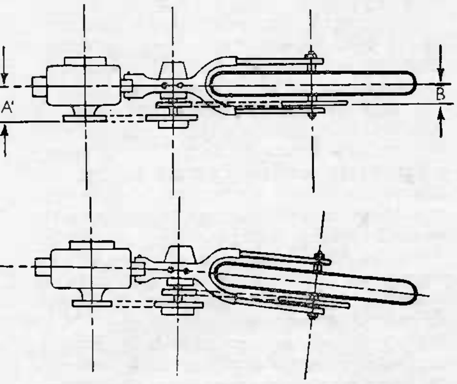
The large-diameter tube-cum-oil-tank allied to duplex tubes: a special Reynolds frame to accommodate a 250 c.c. NSU engine.



to it, in which event vibration of an unpleasant sort may occur. If, however, the frame is made in such a way that it is wider than the chain-lines, the bending effect will be reduced considerably, and this was accomplished to a degree by the addition of the torque-stays mentioned.

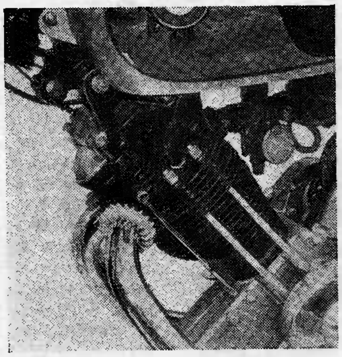
A more satisfactory solution was to bring the chain stays themselves below the gearbox, and continue them forward on each side of the engine (thus enabling it to be positioned low down without sacrificing ground clearance) and forming what was termed the "cradle" frame, a design which won races and competitions for many years. It was introduced in the U.S.A. many years before it became popular in England.

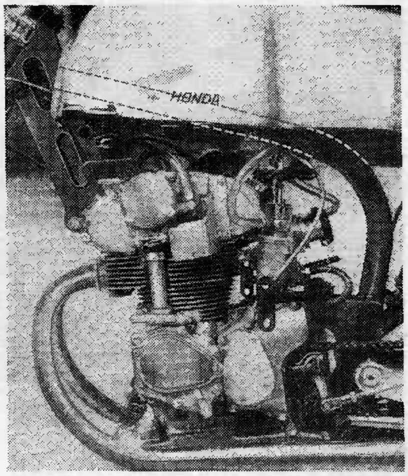
A logical development of this design is to continue the tubes upward to the head-lug to form the "duplex cradle" type. This pattern appears to be immensely strong when inspected sitting on the cradle-tubes on the ground, but it is not necessarily any stronger in torsion than one with a single down-tube, and possibly less strong fore-



How transmission load tends to distort a narrow frame; A and B indicate the offset from the centre line of the two chains.

and-aft unless large-diameter tubes are used or the head-lug is extended downwards by several inches. It is, however, an excellent form of construction for sidecar machines, being triangulated laterally, especially if the top connection is made integrally with the head-lug. B.M.W. have developed a very neat though expensive solution by using duplex tubes which are tapered and also change from circular to oval section as they approach the head-lug to which they are welded.





The engine as "down-tube" on a Panther 120 (above) and on the T.T. Honda (the continuation of the "spine" is shown in dotted lines).

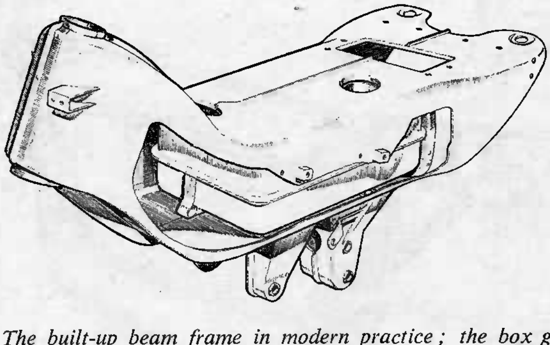
The transverse-twin ABC of the early 'twenties used a logical development of the duplex frame with the tubes spaced so widely apart that they protected the engine in the event of a fall and also formed footboard supports. This construction might well be used again now that partial enclosure has become acceptable, but in its original form it possessed a weakness in that the two tubes were joined to the base of the head with a wide included angle between them. Under fore-and-aft loads these tubes become subjected to bending *and* twisting, in addition to tension from the weight of the powerplant, and in rough conditions would fail in fatigue—a point which would have to be rectified in any future design.

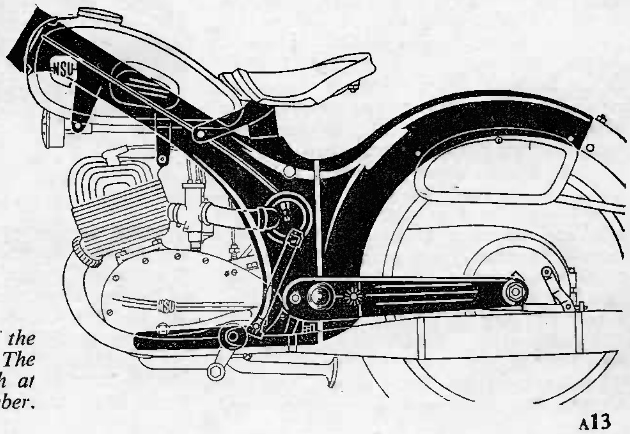
There is, of course, an alternative approach to the whole problem, which is to do away with all forms of lattice-girder or triangulated structure and make the frame as a simple beam—reverting, in fact, to the original velocipede. The essence of the idea is simply to take a large-diameter tube, provided with steering-head bearings at the front and bifurcated to embrace the rear wheel. This results in a simple structure which, with modern facilities, can be made very easily from two light pressings, welded together, though the rear fork-legs should also be made into closed sections by welding-in another strip to form two box-sections.

Open channel sections are extremely weak in torsion and not much better under cross-breaking loads, which cause the flanges to crumple. A good idea of the relative torsional strengths of open and closed sections can be gained by twisting a rectangular tobacco-tin in the fingers, first with the lid open and then with it closed.

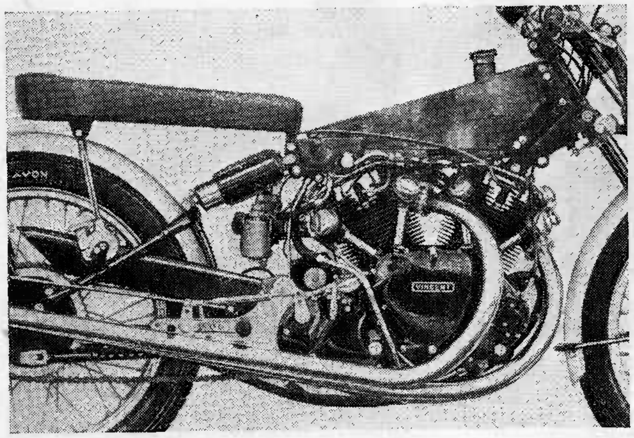
A simple beam frame of the type described is enormously strong in torsion and strong enough vertically to carry moderate loads, so it is an acceptable proposition for mo-peds and pedal-assisted bicycles, the power unit simply being bolted to downward extensions of the tube or backbone and the saddle supported on a pillar, which can be made telescopic to provide both height adjustment and springing. Obviously, local stresses are produced at the base of the pillar which can be allowed for by blending it into the backbone with generous fillet radii, and the backbone may be curved downwards in the centre, partly to keep the engine weight low and partly to provide the "open frame" feature desired by ladies who ride in normal attire.

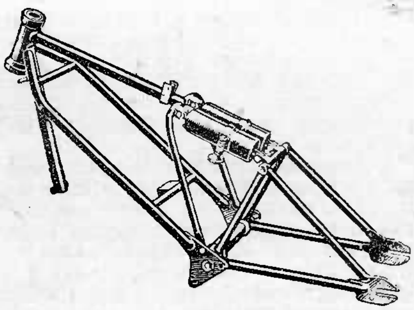
There are innumerable possible variants of this basic conception. For instance, a single tube can slope down to the engine and then up to the saddle, with either rigid or sprung rear forks attached to the rising portion; or the tube can run almost vertically downwards, then horizontally and upwards, this being the underlying construction of the majority of scooters built today. Obviously the greater the length of unsupported tube the more flexible the structure will be, particularly in bending; but on most scooters the idea is acceptable because most of the weight of crew and power-plant is concentrated





The built-up beam frame in modern practice; the box girder of the Ariel "Leader" (above) contains a separate, unstressed fuel tank. The backbone of the NSU "Max" (right) has great depth and strength at the centre. In neither case does the engine act as a frame member.





On the Irving-designed Vincent twin (left), front and rear cylinder heads were attached to a welded backbone-oil-tank, bolted at the front to the head-tube and providing attachment points for the spring units of the suspension at the rear. On the right is a predecessor, the Vincent H.R.D. spring frame of 1928; it was triangulated in side elevation.

over the rear wheel. One or two models, however, are so lacking in rigidity that if the bars are pushed forward with the front brake hard on, the steering-column can be observed to alter its angle.

The NSU pressed-steel frame is an excellent example of the backbone type, the pressings extending down behind the power unit and rearward to provide attachments for the rear springs, thus providing great depth and strength in the centre. The power-unit, though firmly attached at the rear, is merely suspended by a tension link at the front and does little or nothing to stiffen the structure.

Once one has gone to the trouble of making a frame from pressings, it seems reasonable to go a little further and utilize the frame as a tank for either petrol, oil or both. Attractive though this is, it is not always as simple as it looks and is not necessarily economical in material, because a tank can be made in a much lighter gauge of metal than is desirable for a stressed structural member, unless a lot of care is taken to weld in gussets or local reinforcement where necessary.

On the Ariel "Leader," for instance, it has been deemed wiser to fit a simple rectangular tank inside the box-section main frame member, to which the power-unit is attached by downward-extending lugs. In this way the tank can easily be constructed from two pressings with simple welds which are easy to make petrol-tight, and it is unlikely to be damaged even in the most spectacular of crashes. The backbone itself is immensely strong both in bending and torsion, although weakened in the latter respect by the cutaways provided for access to the interior.

It is, however, quite feasible to use a welded backbone as an oil-tank holding about half a gallon without waste of material. This form of construction was adopted on the Vincent twin, the backbone being attached to the front and rear cylinder heads so that in effect the power unit was held up by its ears. This was done for two reasons—first to eliminate the front down-tube and so shorten the wheelbase, and secondly because during overhaul it is easier to lift a light frame off a heavy power unit than it is to juggle the unit out of the frame if only one pair of hands is available.

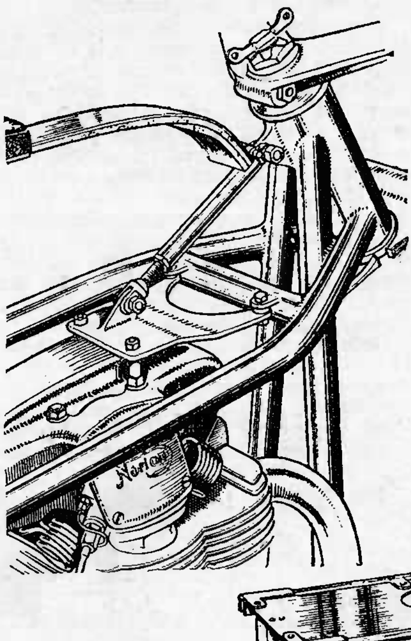
It is interesting to note that the pre-war Vincent single-top-tube brazed frame weighed 12½ lb., and the backbone, of much greater strength in all directions, weighed the same. The experimental design of this backbone had the head-tube welded-in, but if warpage occurred during welding it was almost impossible to eradicate the twist, so a separate head-tube, with the head-lug jig-drilled and bolted in position, was adopted.

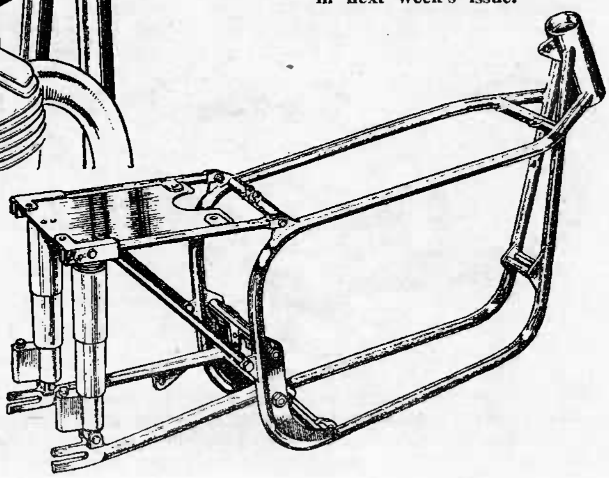
This idea was really an extension of the principle introduced on the early P. and M. and continued in current Panther "big singles" whereby the long-stroke, inclined cylinder engine was bolted to the head-lug and therefore acted as a down-tube. The tensile stresses were carried by four long bolts extending from the bracket on the head right through to the bottom of the crankcase, so that as far as frame stresses were concerned the cast-iron barrel simply acted as a distance-piece. In the racing Honda, the head-lug, formed in this instance from welded tube and sheet-steel pressings, is attached to the cylinder head with transverse bolts, the single top tube curving down behind the unit to form what has come to be termed a "spine" frame; the power-unit is, however, an integral part of this assembly, and the frame is incomplete without it.

In the main, the foregoing has been concerned with the front section of the frame, omitting reference to the rear forks. In an unsprung tubular frame, each side of the fork is usually formed of two, or possibly three, tubes forming a triangle with the rear axle lug as the apex. This structure automatically stiffens the front section and prevents it from "lozenging" under the action of horizontal forces, which may be applied by chain tension or by road shocks. Also, the whole structure, consisting of two triangles attached to a common tube, is extremely rigid in torsion and it is very difficult to twist the axle out of true.

If, however, the triangulation is partially destroyed by cutting off the rear fork-ends in order to attach some form of plunger-springing system, or removed entirely to utilize a swinging-fork design, this stiffening action is largely lost and the main frame should then have to be strong enough in its own right to resist deformation, although many are able to do so only through the additional rigidity supplied by the presence of a bolted-in power unit.

Since the general type and detail design of any rear springing adopted has a bearing on the frame design, this is the logical place to initiate a discussion on rear suspension systems—which will start in next week's issue.





Original version of the famous Norton "Featherbed" frame, as it appeared at the T.T. of 1950. Close-up of the head shows the supplementary bracing tube to the engine-head steady.