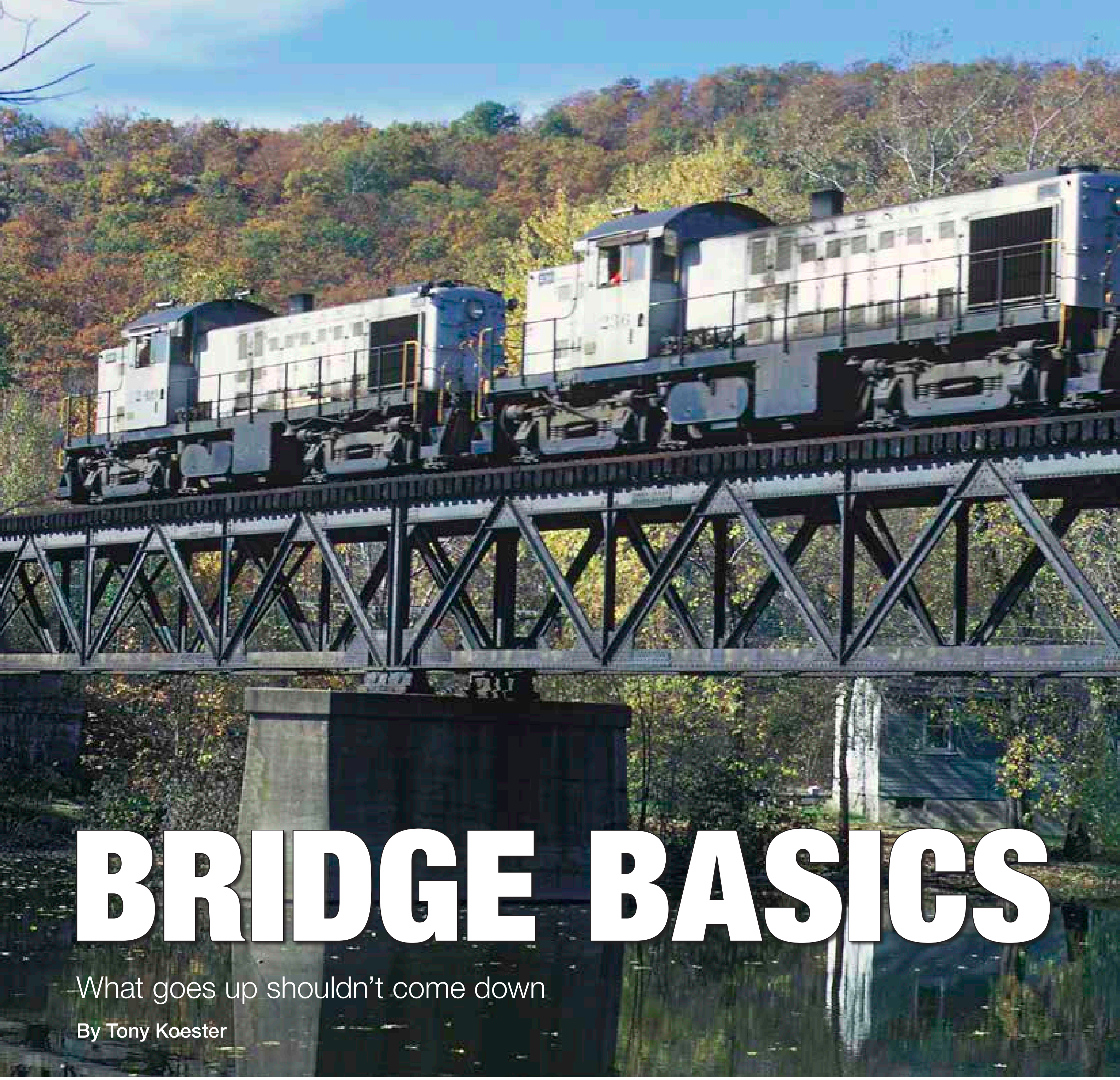

BRIDGE BASICS

What goes up shouldn't come down

By Tony Koester

Nothing grabs a viewer's attention like a train venturing onto a spindly railroad bridge high above a fearsome gorge. If the bridge is a "sideless" design such as a wood trestle or a steel deck girder bridge, so much the better for there appears to be nothing to stop an errant train from plummeting into the chasm.

It follows that modeling bridges is a popular pursuit. That the need for the bridge is frequently artificial – we create the canyons that the bridges must span – matters not. Our desire to add a dramatic or scenic effect is more often at the root of model bridge construction than engineering requirements.

But good engineering practices are still part and parcel of plausible bridge choices and construction. Which raises a fundamental question: If the bridge is holding up the train, what's holding up the bridge?

From beam to bridge

A tree lying across a narrow creek is a bridge. The trunk is a simple beam, the banks are the abutments that support the beam. Like any other beam, the trunk's top side is in compression, its lower side in tension. All will be well as long as nothing too heavy tries to cross that span.

Most bridges, even complex designs, work like that. Short I-beam bridges, like the one shown in **fig. 1,** are kissing cousins to that tree trunk. Deck plate girder bridges, see **fig. 2**, are just tall I beams fabricated from steel plates and angles with tracks set on top. Through-girder bridges, as in **fig. 3**, are essentially the same idea, except that the fabricated I beams are moved upward to the sides of the bridge span to provide more clearance underneath.

A train venturing across a bridge is an attention-getter on any railroad, prototype or model. Picking the right bridge for your layout isn't hard when you understand some design basics. This deck truss bridge is on the New York, Susquehanna & Western RR. Photos by the author unless noted

Fig. 1 I-beam bridge. This short and simple bridge on the Durham & Southern was made from standard steel I beams set on concrete abutments.

Fig. 2 Deck plate girder. This Chicago & North Western (Union Pacific) deck girder bridge was made from large I-beam shapes that were fabricated from plate steel. Bridges like this typically span 30- to 50-foot gaps. Carl Swanson photo

Fig. 3 Through-girder bridge. A through girder bridge is a plate girder with the beams moved up and out to provide more clearance underneath. This curved Clinchfield (CSX) bridge is made from a series of short straight bridges.

Truss bridges, like the deck-truss design shown in the photo above, come in many different types but all of them work in the same way. In fact, if you look carefully at a deck or a through truss bridge, or even a suspension bridge, you'll find that they're really deck girder bridges at heart.

Matching the bridge to the job

Even though the railroad or highway might have to be built on a curve, a wood or steel bridge itself is a series of tangent (straight) sections as in **fig. 3**. While stone and concrete arch bridges

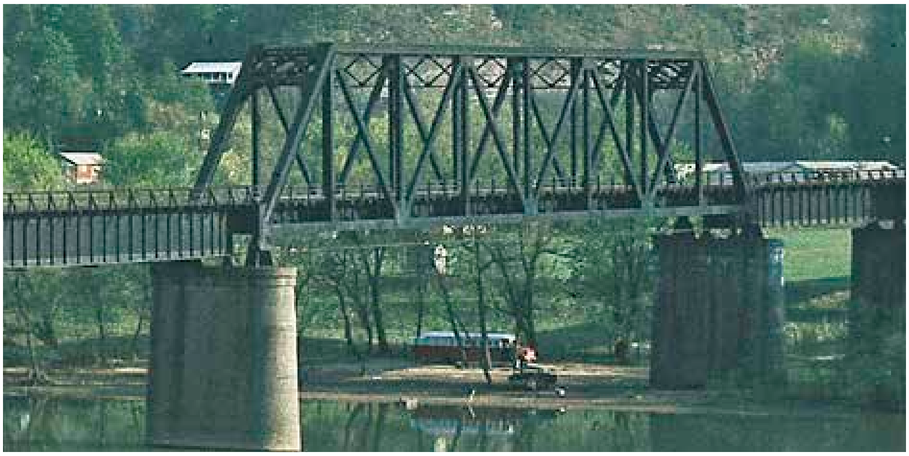

Fig. 4 Through-truss bridge. The Virginian Ry.'s bridge at Gauley, W.Va., is a series of deck girders plus a longer through-truss span to clear river traffic.

Fig. 5 Cross girder. All truss bridge designs are just different ways of supporting the cross girders under the track. This Susquehanna through truss bridge has floor beams fastened below the bottom chord at the end of each panel. The stringers that support the ties are riveted to the floor beams.

can be built to follow a curve, as do some newer girder bridges (thanks to breakthroughs in welded construction), it's generally more prototypical to avoid curving a steel girder or a truss.

Whenever possible, railroads prefer to build girder bridges, as they can often be preassembled and hoisted or rolled into place. Truss bridges have to be assembled on location using supporting false work (supporting timbers).

Railroads also favor deck bridges, as they preclude any possibility of clearance problems in the future. For example, no one imagined double-stack trains when the majority of today's bridges were designed. Since deck bridges are narrower and no extra height is needed to provide vertical clearance, they use less steel, making them less expensive. Also, derailing rolling stock can damage key structural members of a through bridge, but a derailment is less likely to do substantial harm to a deck bridge.

But a deck bridge isn't always possible. The usual problem is that the deck structure interferes with a waterway, roadway, or railroad passing under the bridge, which is often why a bridge was needed in the first place.

The length of each span is also a factor in bridge design. A girder bridge is commonly limited to around 70 feet, although spans exceeding 100 feet have been built. Girders may have up to a 1:15 height-to-length ratio but are more typically around 1:10 or even 1:7. The maximum girder height is 10 feet, so girders longer than 100 feet are rare.

Through truss spans

For longer spans, the open construction of a through truss, like the example in **fig. 4**, is a practical choice. Note that bridges like this, spanning an entire valley filled with rivers and roads are often made up of a combination of spans of varying lengths and construction.

In a through truss bridge, the lacework of trusses are little more than supports for the cross girders that underlie the roadbed. The underfloor girders are shown in **fig. 5**.

Pony trusses (through truss spans with no overhead cross members) are limited to lengths of 100 feet. Through trusses are favored for spans of 100 to as long as 500 feet.

As illustrated in "Truss bridge types" at left, several truss patterns are in common use. Regardless of pattern, the height-to-span ratio is typically 1:6 or 1:7 today but was as great as 1:10 in the past, making a 350-foot truss bridge at least 35 feet high.

The bridge minimum inside clearance height is 22 feet, which results in

Truss bridge types

Truss bridge designers have never agreed that one arrangement of truss members is inherently superior to another. Several types of truss configurations have emerged since the days when truss bridges were fabricated from wood and iron rods. This illustration shows five of the common types. Members in tension are shown in red; those in compression in blue. The dotted lines represent counters, used when extra strength is required. Tension members are usually thinner and may be steel cables, rods, or flat bars. Compression members tend to be thicker; remember, you can't push a string! *–T.K.*

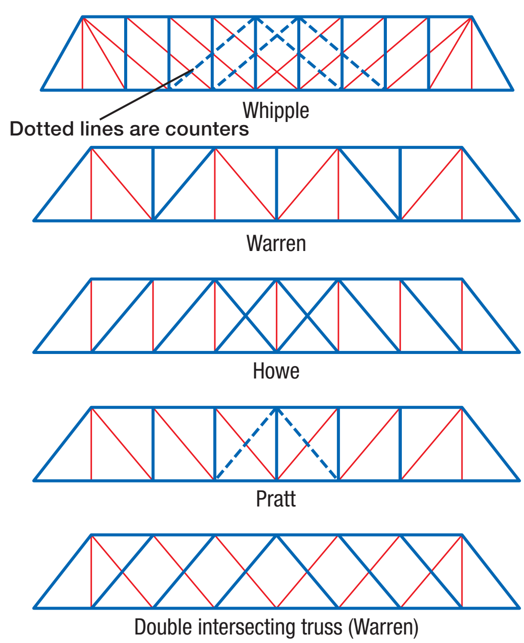

Illustration by Theo Cobb

a 27-foot minimum truss height, so shorter bridges will naturally have a higher height-to-length ratio.

The diagonals on truss bridges are placed at a 45-degree angle or steeper, and partial-width panels are avoided. If there are an uneven number of panels, the center truss panel will resemble a pair of overlapped panels to maintain the symmetry of the bridge.

Masonry bridges

Stone or concrete bridges are often components of signature scenes that help to pin down the prototype being modeled. For example, the built-to-last-forever Pennsylvania RR was a proponent of stone-arch bridge construction.

A masonry bridge will often outlast the railroad company that built it. **Figure 6** shows the famous Starrucca Viaduct, built in 1848 by the Erie RR and still in service today. The key to a stone-arch bridge's structure is the arching row of carefully fitted stone "voussoirs" that vault up and inwards to the wedge-shaped keystone. You can't just cut an arched opening in a stone wall casting and proclaim victory.

On the prototype, such bridges are expensive to build and required the equivalent of a temporary wood trestle to support the arch as it was being laid, so short lines or branches were unlikely to employ stone arch bridges.

Simple concrete bridges and viaducts are durable and practical choices for short spans, as in the rural road shown in **fig. 7**. These bridges are easily scratchbuilt from balsa and cardstock. Kits and castings for various stone and concrete bridges and culverts are commercially available.

Various types of abutments and piers are also available. There is usually a noticeable degree of "batter" or upward taper to concrete or masonry structures, which is very noticeable on Erie's Starrucca Viaduct, and the upstream side of piers placed in moving water have a cut-water or pointed edge.

Supporting the ends

This brings us to an important tenet of basic bridge design: You must support both ends of a beam. Just as the banks of the stream support our tree trunk bridge, abutments, piers, or ties to a supporting truss are needed at both ends of each and every beam unless the bridge you're modeling is a relatively uncommon cantilever span, in which the beams meet in mid-air.

Beam supports are where too many model builders get it wrong. I've seen bridge spans supported at the center of each span instead of at the ends. I've

Fig. 6 Stone-arch viaduct. The Erie RR's massive Starrucca Viaduct in Lanesboro, Pa., was built from locally quarried stone in 1848. The bridge remains in active service today, more than 150 years after its completion. Note the "batter" (slope) of each pier. Matthew Van Hattem photo

Fig. 7 Concrete viaduct. Box-style concrete viaducts, like this example in Illinois, are an inexpensive way to span a small road or stream. Carl Swanson photo

Short course in bridge design

Here are some bridge do's and don'ts to keep in mind.

- Most bridges are deck girder bridges, some disguised as truss bridges. Be sure that both ends of each beam or girder are supported by an abutment or pier or tied to a truss at a panel joint.
- Don't butt a bridge to an abutment; rather, rest it atop a shelf on the abutment. Gravity pulls downward, so support each span from below.
- A bridge's height-to-length ratio is typically between 1:6 and 1:10. A long, thin bridge made by butting several girders together will require intermediate support at each girder joint.
- The rails on a curved bridge can't arc outside of the supporting beams or girders placed under the ties.
- Trusses or girders shouldn't be curved.
- Stone arch bridges require an arching row of stones that spring upward to a centered keystone.
- Suspension bridges and railroads don't mix. – *T.K.*

Fig. 8 Deck girder viaducts. Steel deck girder viaducts are made of fabricated I beams atop supporting towers. This bridge on the Indiana RR in southern Indiana has girders of identical depth regardless of their length. Some bridge designs use thinner girders for shorter spans.

Fig. 9 Mixing and matching. The Virginian used a combination of deck bridge designs to span the New River, a Norfolk & Western line, and a highway at Glen Lynn, Va. Note how the center tower's top section is vertical to match the deck truss span to the right. Thomas D. Dressler photo

seen bridges butted up to the front face of an abutment rather than sitting atop a shelf. As gravity always pulls downward, this is clearly a problem.

Bridges are very simple as long as you keep in mind the need to support the ends of every span. Each end of each girder on a through truss bridge must be connected to a cross member that is, in turn, tied to the main truss at the end of each panel.

Modeling bridges

Modelers today have a superb selection of plastic bridge kits and components to work with, especially in HO. Splendidly detailed brass deck and truss bridges of several standard types have also been imported.

Micro Engineering makes several variants of deck girder viaducts in HO and N scales, complete with deck girders of 30 and 50 feet and two types of steel towers. To span an even greater distance between the towers, I've substituted girders from Central Valley's 72-foot through-girder bridge kit with the rounded ends of the girders cut off.

Figure 8 is an example of a typical steel deck girder viaduct. The deeper the girder, the longer the distance it can safely span, and the greater the bridge's Cooper rating.

Bridges are rated using the Cooper system, which to this day uses steam locomotive axle loadings to determine a bridge's strength. A bridge built to handle a modest-sized locomotive with 50,000 pounds on each driving axle has a Cooper rating of E50 – that's a rather light bridge by late steam era or modern standards. Cooper ratings of E72 or greater are now common, even though diesels are much easier on bridges than were steam locomotives as there is no main-rod-induced "dynamic augment" slamming down on the bridge structure with each revolution of the drivers.

In HO, Central Valley also makes a beautiful pin-connected, Pratt through truss bridge. In a pin-connected bridge, the lower structure members are connected to the vertical members with thick pins, instead of being riveted together. Compared to riveted joints, it was easier to calculate the forces acting on a pin joint. That's why early engineers favored the design. It was also a simpler task for workers to erect pin-connected trusses in the field.

Walthers manufactures single- and double-track through truss spans in HO, and the double-track version in N. These are modern Warren truss bridges, easily identified by the pattern (think "W for Warren") of the panel members.

Walthers also makes a plastic wood trestle kit. This replicates a pile trestle, in which round piles are driven into the ground by a pile-driver.

A frame trestle looks similar but has square timbers on footings rather than piles driven into the soil. Numerous kits and bent-making jigs have been offered to speed construction of such bridges.

Combination designs

In the real world, one size doesn't fit all. A standard bridge design may work just fine in one location, while another location demands more engineering creativity. **Figure 9** is an example of a bridge that freely mixes trusses, girders, concrete, and steel.

As discussed in "Problems and solutions" at right, railroad bridges are individual solutions to individual problems. Don't be reluctant to mix and match construction materials and designs if the need arises

Tower construction

Even a cursory study of prototype deck girder viaducts will show that the variations of tower construction and girder type are endless. Some railroads employ girders of a single thickness regardless of their length, as in **fig. 8**. Other railroads use thinner girders for the shorter spans atop each tower.

To prevent the legs from splaying, the bottoms of the tower legs are almost always connected by cross members. And the girder span between towers is often equal to or twice as long as the span atop each tower.

With the exception of fairly unusual designs like cantilever or suspended-span bridges, one of the main concerns of a bridge engineer is adequately supporting each end of each girder atop a strong abutment, pier, or tower. As an added complication, the bridges don't just sit there – they expand or contract with temperature fluctuations. Consequently, one end of a bridge is typically fixed in place; the other is free to slide on steel plates or rollers. Setting short bridge spans on simple plates is sufficient, but long bridges require pedestal bases that are quite visible.

Where short girders abut longer ones, a stepped pier accommodates the difference in height.

When a deck girder bridge is built on a grade, the supporting towers will be level on top, and shims are placed on the upgrade end of each tower.

If I've whetted your appetite, I think you'll find that Jeff Wilson's reference, *The Model Railroader's Guide to Bridges, Trestles & Tunnels* (Kalmbach, 2005), to be of considerable value. I also devoted a chapter of my book, *Realistic Model Railroad Building Blocks* (Kalmbach, 2005), to bridge scenes. You may also want to refer to Harold Russell's "ABCs of bridges" series in MR's July through December 1988 issues. **MR**

Problems and solutions

Spanning the lower, curving main line on the author's Allegheny Midland HO scale layout was a challenge, which Tony solved by modifying a Walthers through-truss bridge kit.

This bridge has been skewed by one panel to accommodate the angle between the railroad and the waterway while keeping the under-track cross girders at right angles to the rails. Note the X-shaped "over-lapped" center panel.

When your job involves moving heavy loads, the world is an annoying place. Hills, valleys, and rivers conspire against the efficient movement of trains. A railroad locating engineer needs to find a solution that best overcomes the challenge at hand, and that solution will be largely based on his railroad's financial circumstances. A logging railroad won't build a Starrucca Viaduct, no matter how tempting the trees are on the other side of the valley.

For model railroaders, curves can be particularly problematic because our curves are much sharper than the prototype's. You can visualize the concern by drawing a 30"-radius curve and then trying to support it with a series of deck or through spans. The rails will arc outboard of the sides of a deck girder span, and they will come perilously close to the sides of a through girder or truss. Drop the curve's radius to 24" and the problem worsens.

I needed a bridge for a 30" curve on my former layout. Adding to the challenge was a line below crossing at an angle well under 90 degrees, which called for a long span. But the longer the span, the father apart its sides would have to be to accommodate the 30" curve.

As the top photo shows, I solved my dilemma by buying a Walthers through truss bridge, assembled the sides, and blocked them up under the curving main line. The problem was then reduced to fitting a series of Micro Engineering deck girders under the rails, adjusting their lengths so each ended at a panel junction on the truss bridge, then connecting each end of each girder to the end of a truss panel with a short cross girder. Girders must be spaced a minimum of 6'-6" apart (7'-6" for spans greater than 75 feet), and the curving rails can't be located outside of either girder.

The lower photo shows how girder and truss bridges are often skewed, with one side offset one or more panels to bridge an angled road or stream. Model or prototype, the creative approach pays off – *T.K.*