The heaviest locomotives in actual service on thirty-six American railways are given in Table 2, which table also indicates contemplated increases.

The increases from the 22,000-lb. grasshopper used on the Baltimore & Ohio in 1835 to the articulated type weighing 463,000 lbs. has been rapid and remarkable and is illustrated by the following data, which shows the heaviest engines in actual service on the Baltimore & Ohio Railroad from 1835 to date:

Data Showing Engine Development on Baltimore and Ohio Railroad.

Type.	Date.	Weight.
Grasshopper	1835	22,000 lbs.
Winans' Camel, 8-wheel	1851	74,600 "
Perkins' 10-wheel	1863	90,800 "
Consolidation	1873	105,200 "
Consolidation	1881	108,600 "
Mogul	1886	113,200 "
Consolidation	1887	115,600 "
Consolidation	1888	125,000 "
Baldwin, 10-wheel	1890	133,000 "
Consolidation	1892	134,200 "
Consolidation	1894	160,800 "
Electric Motor	1895	190,000 "
Consolidation	1905	208,500 "
Pacific	1906	229,500 "
Articulated	1911	463,000 "

The above shows an increase from 133,000 lbs. in 1890 to 463,000 lbs. in 1911, which is about 248 per cent. in the past 21 years. There are much heavier engines in use on other roads.

The maximum axle load in 1835 was 5,500 lbs., while at present it has gone beyond 65,000 lbs., with limit not yet reached.

Table 1—Heaviest Locomotives of Each Type.

Type.	Engine Alone.		*Double-Header.		
	Weight, Lbs.	Wheel Base, Ft.	Weight, Lbs.	Wheel Base, Ft.	Weight, Per Ft.
Atlantic	214,800	30.79	728,400	127.76	5,700
Prairie	244,700	34.25	807,500	132.92	6,070
Consolidation	260,100	26.50	860,400	131.81	6,520
12 Wheel	262,000	27.08	817,400	130.15	6,280
Decapod	267,000	29.83	802,000	127.00	6,320
Pacific	270,000	35.20	865,400	142.48	6,070
Mikado	305,000	35.00	960,000	150.00	6,400
12 Wheel Articulated	334,500	30.66	473,800	64.56	7,340
10 Coupled	361,000	43.50	1,074,000	161.00	6,670
20 Wheel Articulated	478,000	59.80	703,600	99.70	7,060
16 Wheel Articulated	493,000	40.17	588,000	82.58	7,130
24 Wheel Articulated	616,000	65.92	841,600	105.82	7,950
12 Wheel Electric	300,400	38.50	600,800	86.50	6,950
16 Wheel Electric	320,000	44.22	640,000	102.84	6,220
†Cooper's E-50	225,000	23.00	710,000	104.00	6,830
†Cooper's E-60	270,000	23.00	852,000	104.00	8,190

*Weight and wheel base for articulated engines are given for one engine and tender.

†Cooper's E-50 and E-60 typical consolidation engines are given for comparison.

Bridge Specification Requirements.

The specification loading for bridge design as now in use by the various railroads is given in Table 3, which table also gives the impact allowances and permissible unit-stresses. The simplest manner of comparing these various specified loadings, including their different impacts and unit-stresses, is by reducing them to an equivalent loading on the basis of the American Railway Engineering Association Specifications. These specifications provide for a consolidation type of engine known as Cooper's E-40, E-50, E-60 series, depending upon whether the weight on each driving axle is forty, fifty or sixty thousand pounds. The equivalent loading given in the sixth column of Table 3, therefore, means that the specified loading, impacts and unit stresses, as adopted by the various railways, are practically equivalent in their effects on bridges to the Cooper's E series loading noted, when used in connection with the American Railway Engineering Association Specifications.

This table also shows changes under consideration by a number of railways. It will be observed by reference to the table, column 6, that eleven roads are building bridges for a strength practically equal to E-60 bridges, four for E-57, seven for E-55, one for E-53, eleven for E-50, four for loads under E-50 and one for loads over E-60. Of those roads which are now designing bridges for E-50 or under, two propose the change to E-60 and three to loading in excess of E-50 in the near future.

Table 2—Heaviest Locomotives in Actual Service on 36 American Railways.

	Locomotives in Service.		Under Consideration.	
Railway.	Type.	Weight Lbs.	Type.	Weight, Lbs.
N. Y., N. H. & H.	Pacific	229,500	Pacific	285,000
B. & M.	Pacific	equal to E-43	....	....
N. Y. C. Lines	Pacific	266,100	....	....
Erie	Consolidation	260,100	Mikado	305,000
P. R. R.	Pacific	269,800	....	....
L. V.	Pacific	241,400	....	....
P. & R.	Consolidation	222,000	....	....
B. & O.	Mallet	463,000	....	....
N. & W.	Mallet	400,000	....	....
C. & O.	Mallet	392,000	Mallet	400,000
Virginian	Mallet	455,000	....	....
S. A. L.	Consolidation	212,000	....	....
Southern	Mallet	366,000	....	....
A. C. L.	Consolidation	171,000	....	....
L. & N.	Consolidation	224,000	....	....
Wabash	Consolidation	223,800	....	....
B. & L. E.	Consolidation	254,000	....	....
I. C.	Consolidation	223,000	Mikado	280,000
Pere Marquette	Consolidation	217,000	....	....
M., St. Paul & S. S. M.	Pacific	253,800	....	....
C. & A.	Mallet	323,400	....	....
C. & N. W.	Pacific	238,000	....	....
Great Northern	Consolidation	216,600	....	....
C., M. & St. P.	Mikado	260,500	....	....
C., B. & Q.	Mallet	354,500	Mallet	463,000
A., T. & S. F.	Double Santa Fe	616,000	....	....
C., R. I. & P.	Consolidation	238,900	....	....
N. P.	Mallet	435,200	....	....
M. P.	Pacific	251,000	Mallet	?
S. P.	Mallet	437,000	....	....
St. L. & S. F.	Mallet	416,000	....	....
M., K. & T.	Pacific	228,000	....	....
Grand Trunk	Consolidation	211,200	Mikado	275,000 abt.
Canadian Pacific	Mallet	261,900	....	....
C. N.	Consolidation	181,400	Consol	?
N. Rys. of M.	Mallet	338,000	....	....

It may be reasonably assumed that the specifications in force, or the proposed changes, represent the views of the engineering department of the various railways relative to the sufficiency of the present requirements for meeting future conditions, and on this assumption:

One road considers E-65 insufficient,
Thirteen roads consider E-60 sufficient,
Fifteen roads consider E-55 sufficient,
Ten roads consider E-50 sufficient.

In order to determine the relative effects, on bridges, of the various heaviest types of engines in service and the usual specification E-50 and E-60 class, the maximum shearing and bending stresses produced by each type were calculated for spans ranging from 10 ft. to 100 ft., all locomotives, excepting the articulated types, being considered as running double-headers drawing a train of 5,000 lbs. per foot of track. On the assumption that the maximum stress produced by E-50 class is represented by unity, the proportional maximum stress produced by the various locomotives on bridges under 100 ft. is given in Table 4.

It is fortunate for our bridges that the stresses produced by the heaviest engines are not in direct proportion to the weight as compared with E-50 type. For instance, the 24-wheel articulated engine weighs 174 per cent. more than E-50, but produces increased stresses varying from 15 per cent. to 33 per cent. The 16-wheel articulated type weighs 119 per cent. more, but produces increased stresses varying from 26 per cent. to 34 per cent. The 20-wheel articulated type weighs 112 per cent. more, while the stresses are increased