9-72

ROCK BOLT STUDY

CARLIN TUNNELS

MAY 1972

E.A. NO. 70280

PROJECT NO. I-080-4 (11) 277

ENGINEERING GEOLOGY & FOUNDATION SECTION
MATERIALS & TESTING DIVISION

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INTRODUCTION

At the request of Bridge Division, a study was initiated by this section during December of 1971, to determine the feasibility of using rock bolts for lateral support of retaining walls at the portals of the Carlin Canyon Tunnels. This study included the installation and testing of 26 rock bolts at locations near the proposed retaining walls. Of the 26 bolts installed, 17 were near the East Portal location and 9 were near the West Portal location. (See page i).

"Williams Hollow Groutable Rebar Rock Bolts" were used exclusively at both locations. These bolts utilized an expansion shell - type anchor. All of the bolts installed were 8 feet long and had a nominal diameter of 1 inch. When properly installed in suitable rock, these bolts have a rated ultimate capacity of 40,000 pounds and a maximum working load of 30,000 pounds. (See page ii).

GENERAL

Rock reinforcement is most effective in jointed and bedded rocks where the reinforcement can integrate the entire mass into a structural entity. The rocks which occur at the Carlin Tunnel site are moderately to badly jointed and fractured, and weathering has produced a parting or separation plane parallel to the bedding. It is along these planes where failure often takes place. It is felt that rock bolts properly spaced and installed in the rock at Carlin Tunnel will serve as adequate reinforcement.

While rock bolts are often used to pin individual blocks of rock, to support portions of the construction equipment, or even to stablize

a direct support system, the term rock reinforcement is intended to apply to pattern bolting for purposes of forming a structural member in the rock mass. It has been aptly demonstrated by photo elastic methods and by models that rock bolts properly installed on a pattern create a compressive stress normal to the free surface of the excavation. There is created then an envelope of compression, which in itself is reinforcement to the rock mass

INSTALLATION

Two types of rock bolts are in general use which are installed for the purpose of stressing rock. These bolts are classified by the type of anchorage and consist of those bolts with a slot and wedge and those utilizing some form of an expansion shell.

The expansion shell type bolt was choosen for installation at the Carlin Tunnels because they could be prestressed easily and because our experience in installation of both types proved installation of the expansion shell type easier.

Two different procedures were followed for the installation of the rock bolts at both test locations. One of the methods included drilling a hole into the rock to a depth greater than eight feet and inserting the rock bolt "anchor-end first" into the hole. The anchor was then mobilized by torqueing the exposed end of the bolt using a special locking nut and a torque wrench. The hex nut and keyhole plate were then secured by torqueing the hex nut. The rock bolt hole was then filled with an expansive grout.

The second method followed was essentially the same as the first method except the bolts were first prestressed to a load of 30,000 pounds using a center hole jack immediately before the hex nut and keyhole plate were secured.

At the east portal test site, 9 out of the 17 rock bolts installed were prestressed using the above procedure and 4 of 9 bolts installed at the west portal locations were prestressed.

Some difficulty was encountered during the installation of some of these bolts. Some of the holes were reamed too large resulting in poor anchorage between rock and bolt. It was learned during this study that guides should be kept in place during drilling operations to avoid "whipping" of the drill steel which may have resulted in the reaming of the overly large holes.

It was originally planned to torque all of the hex nuts to 250 foot pounds during installation; however, the applied torque ranged from 140 to 260 foot pounds due to slippage between the rock bolt anchor and the rock mass. Also, some of the bolts could not be prestressed to the planned 30,000 pounds without pulling the bolt.

TESTING PROGRAM

The test procedure followed was to load each rock bolt in one ton increments and measure the resulting elongation until either the maximum working load of the bolt was exceeded or the anchorage failed. This was accomplished by the use of a hydraulic center hole jack to load each rock bolt and a dial gauge to measure the resulting elongation.

To test the pre-stressed bolts it was necessary to first remove the hex nut from the rock bolt to engage the rock bolt to the center - hole jack.

The load vs. elongation curves of each bolt tested are shown in the appendix.

Some difficulty was experienced in properly seating the jacking frame on the rock, thus the first cycle of each test was disregarded due to the crushing of the high points below the jacking frame.

Although the majority of the bolts reached the working loads of the steel and their design values, it is felt that loads for prestressed bolts should have been somewhat higher. Because of the testing method used, due to the design of the jacking frame, it was necessary to relieve the tension on the bolt to allow testing. Therefore the bolt was not in a prestressed state during the test.

EAST PORTAL RESULTS

The first tests were performed on the torqued and grouted bolts. Of the eight installed only seven could be tested. Bolt No. 1 could not be torqued to an adequate limit and therefore was not used. Of the seven tested, two (No. 2 and No. 3) failed immediately. These three bolts (No. 1, No. 2 and No. 3) were installed in a highly sheared zone and it is felt that proper anchorage was really never attained. Of the five remaining bolts tested (No. 4 through No. 9) all held to beyond the maximum working load. Elongation varied from .02 to .005 for loads of 30,000 pounds. Bolts showed less elongation from south to north indicating better rock quality from south to north.

Nine bolts were installed on the east portal for tests of prestressed bolts. Of the nine installed only five could be prestressed to 30,000 pounds. This poor number of prestressing was probably due to the hole diameter being too large or extremely poor rock quality. Bolts No. 6 and 7 were grouted and tested even though they could not be prestressed properly. Bolt No. 6 failed immediately after loading, whereas bolt No. 7 held to the maximum working load of the bolt. Total elongation ranged from 0.00 to 0.015 inches for loads up to 30,000 pounds. All bolts failed at loads from 34 to 44 thousand pounds.

WEST PORTAL RESULTS

Five grouted bolts were installed for tests on the west portal. These bolts varied in foot pounds of torque from 140 to 260.

Elongation varied from 0.00 to 0.015 inches with all bolts holding to the maximum working load of 30,000 pounds.

Four prestressed bolts were installed and tested at the west portal. All bolts held to the required loads with elongation varying from 0.00 to 0.01. The only problem experienced with the tests at the west abutments was that the grout around bolt 4 ran out after the grouting operation, therefore this bolt did not test out as high as the others of this series.

CONCLUSION

Of the twenty-three bolts tested on this study, all but three held to the maximum working load of 30,000 pounds. The three bolts that did fail were located in either extremely fractured or earthy material or the bolts could not properly be torqued due to the hole being oversized.

It is the opinion of this section that rock bolts can safely be used for the lateral support of the portal walls on the Carlin Canyon Tunnels if an adequate testing program is carried out during construction. Due to the relatively nonuniform rock conditions at the tunnel site, it is recommended that one out of every fifty rock bolts installed be tested.

Respectfully submitted

David G. Cochran
Engineering Geologist III

Daniel J. Keating
Civil Engineer I

APPENDIX

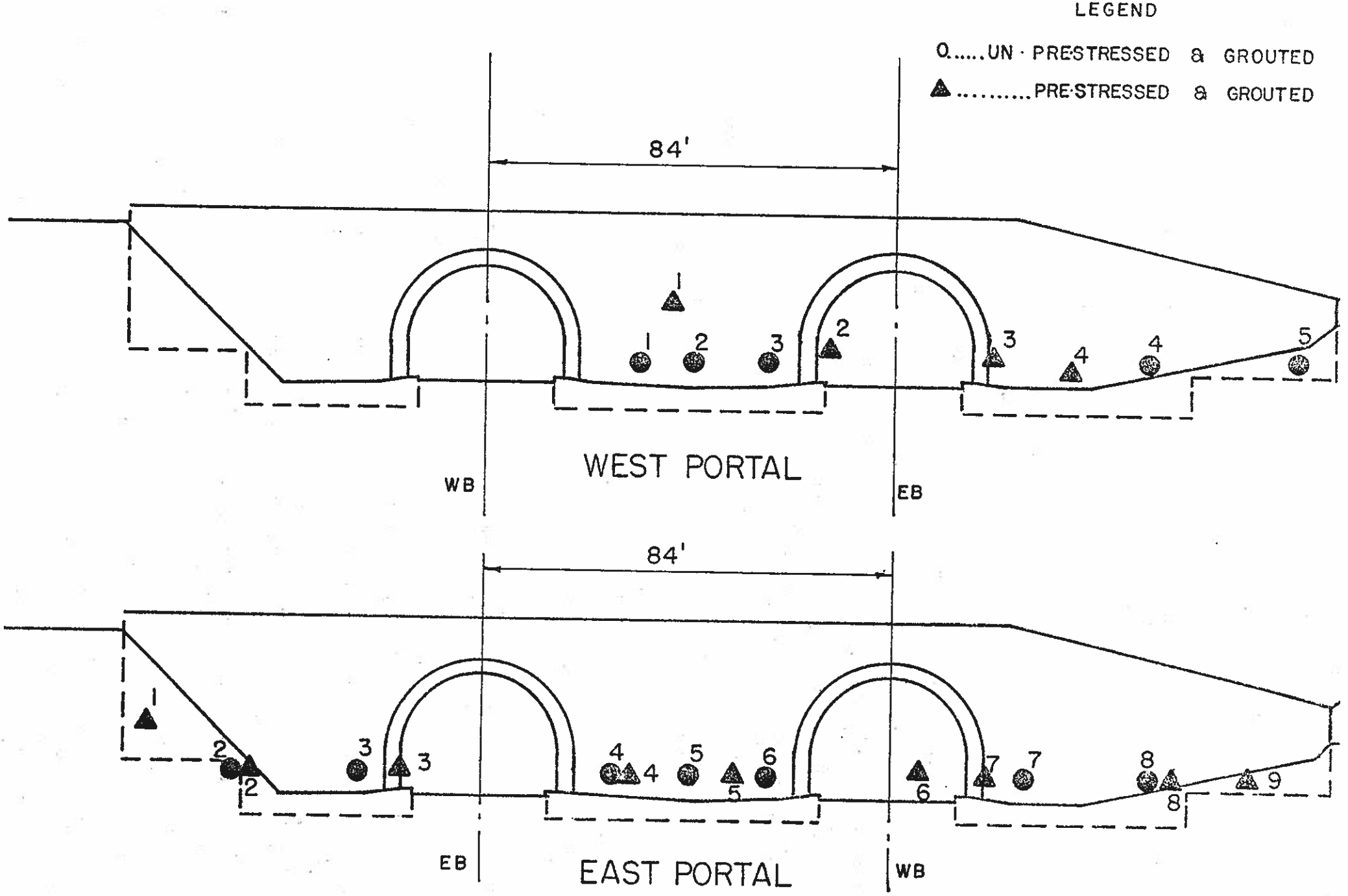
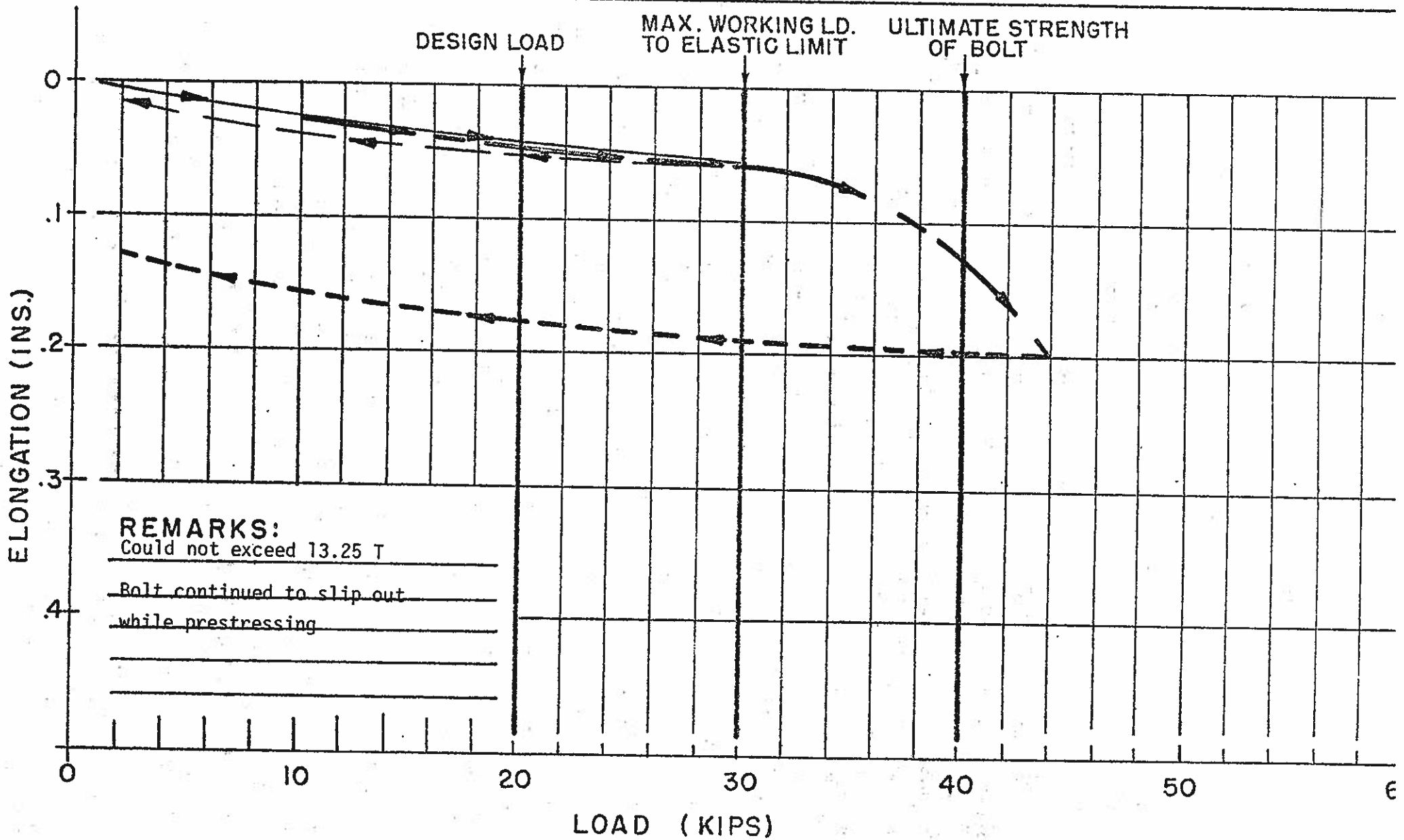

LEGEND
O.....UN · PRESTRESSED & GROUTED
▲.....PRE-STRESSED & GROUTED
84'
WB
WEST PORTAL
EB
84'
EB
EAST PORTAL
WB

FIGURE 1

▲ West PORTAL 44' Lt. Eb STA. 1777+25+

ROCK BOLT NO. 1A

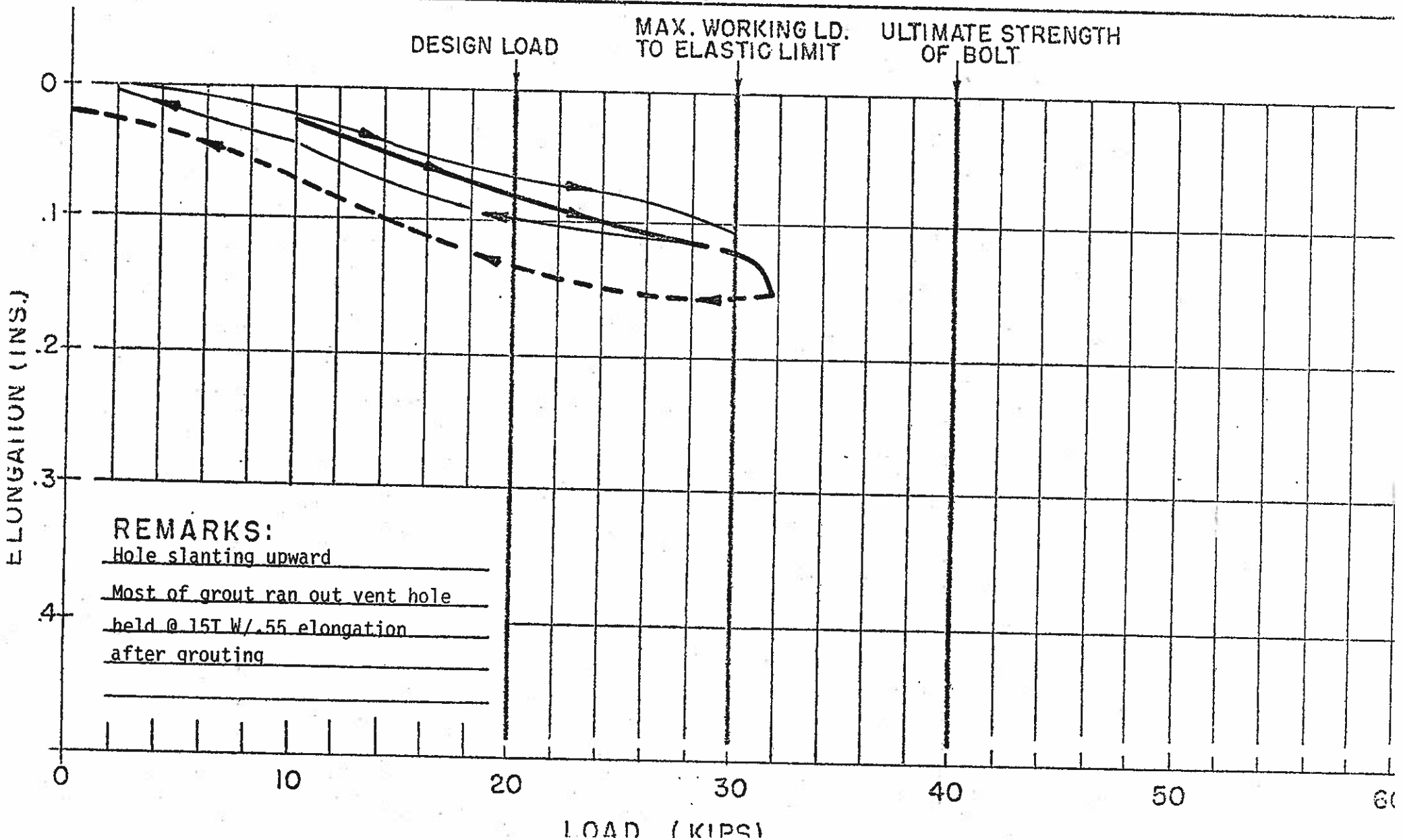
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



▲ West PORTAL 13' Lt. Eb STA. 1777 + 25+

ROCK BOLT NO. 2A

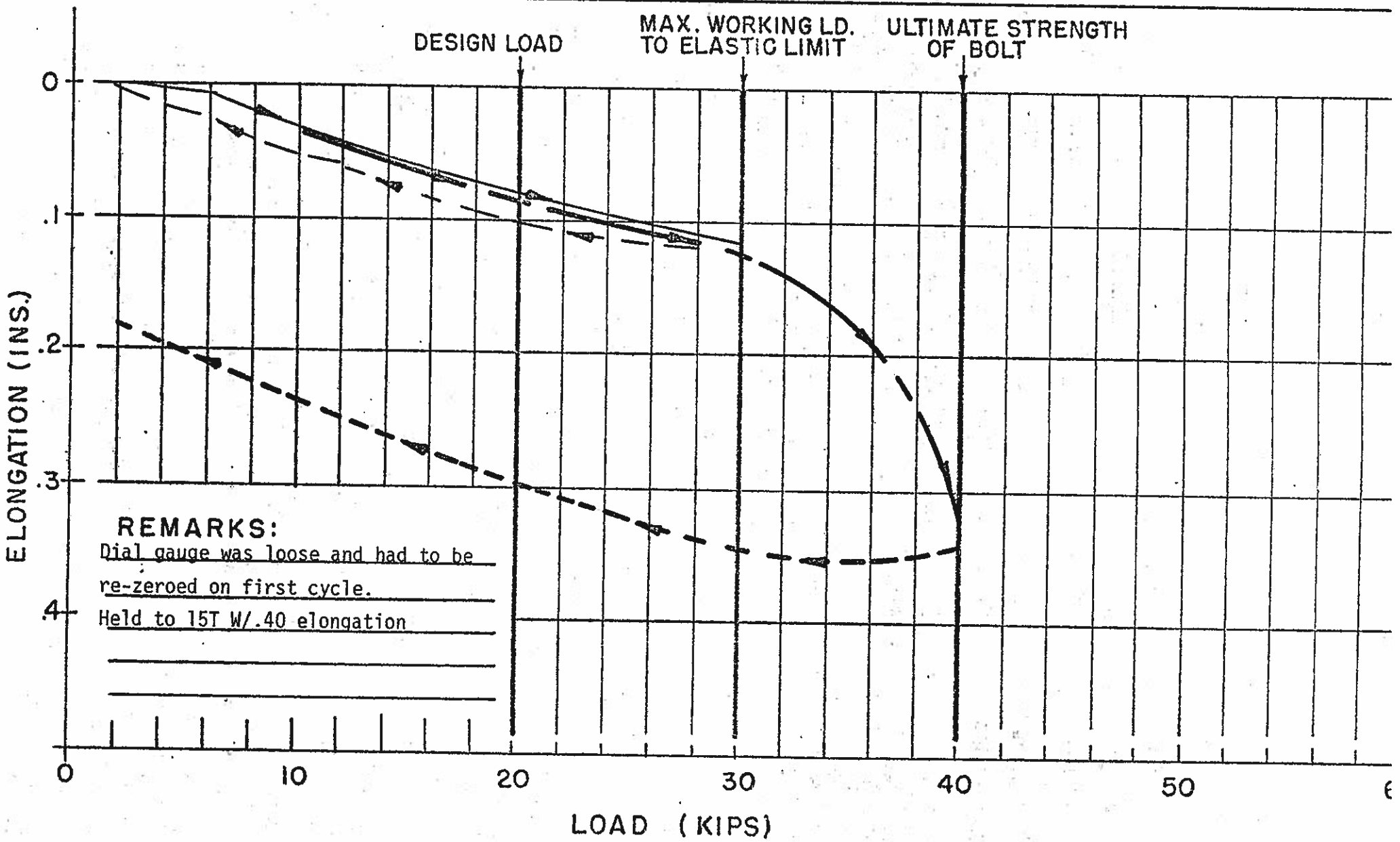
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



▲ West PORTAL 19' Rt. Eb STA. 1777 +25

ROCK BOLT NO. 3A

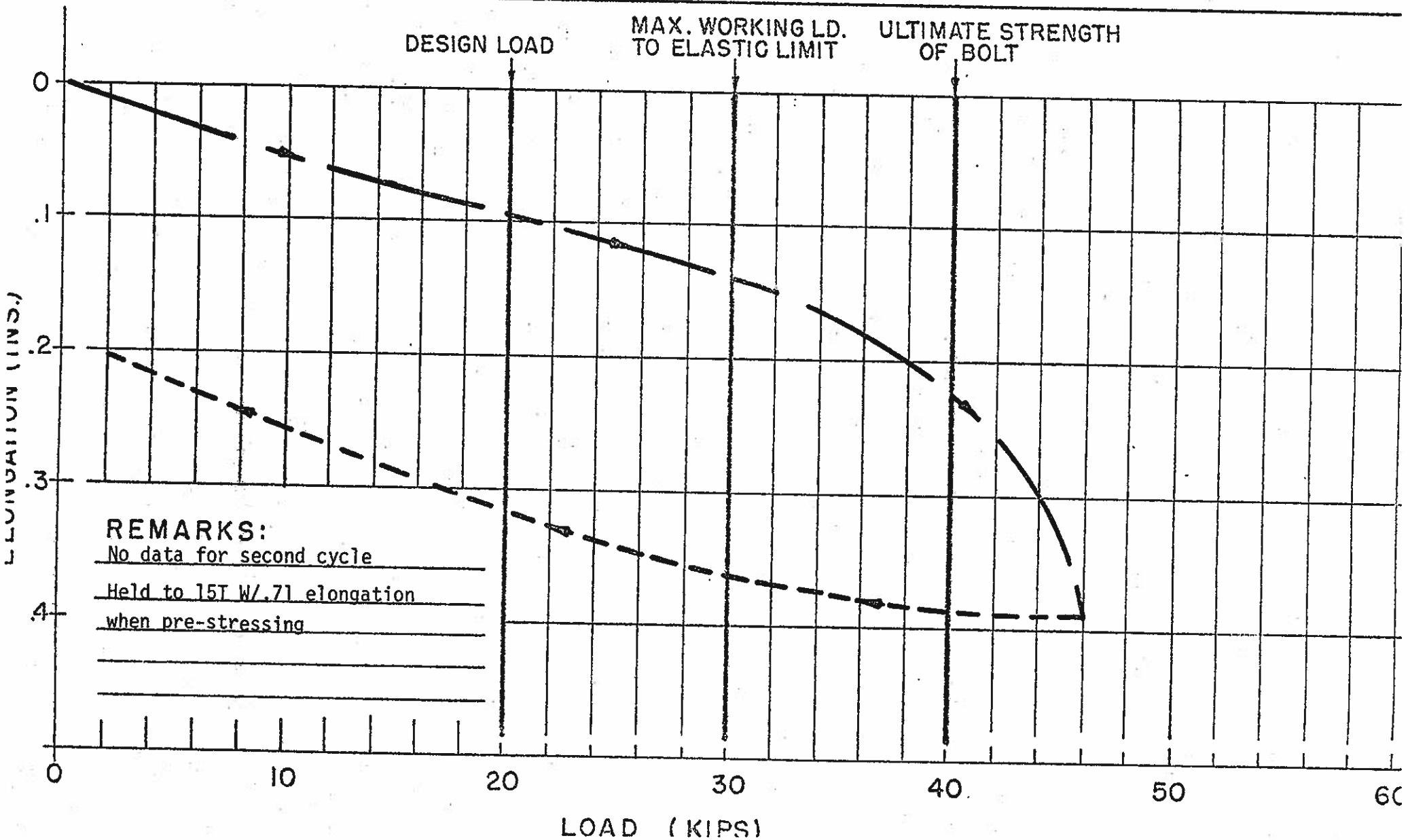
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



▲ West PORTAL 35' Rt. Eb STA. 177+25+

ROCK BOLT NO. 4A

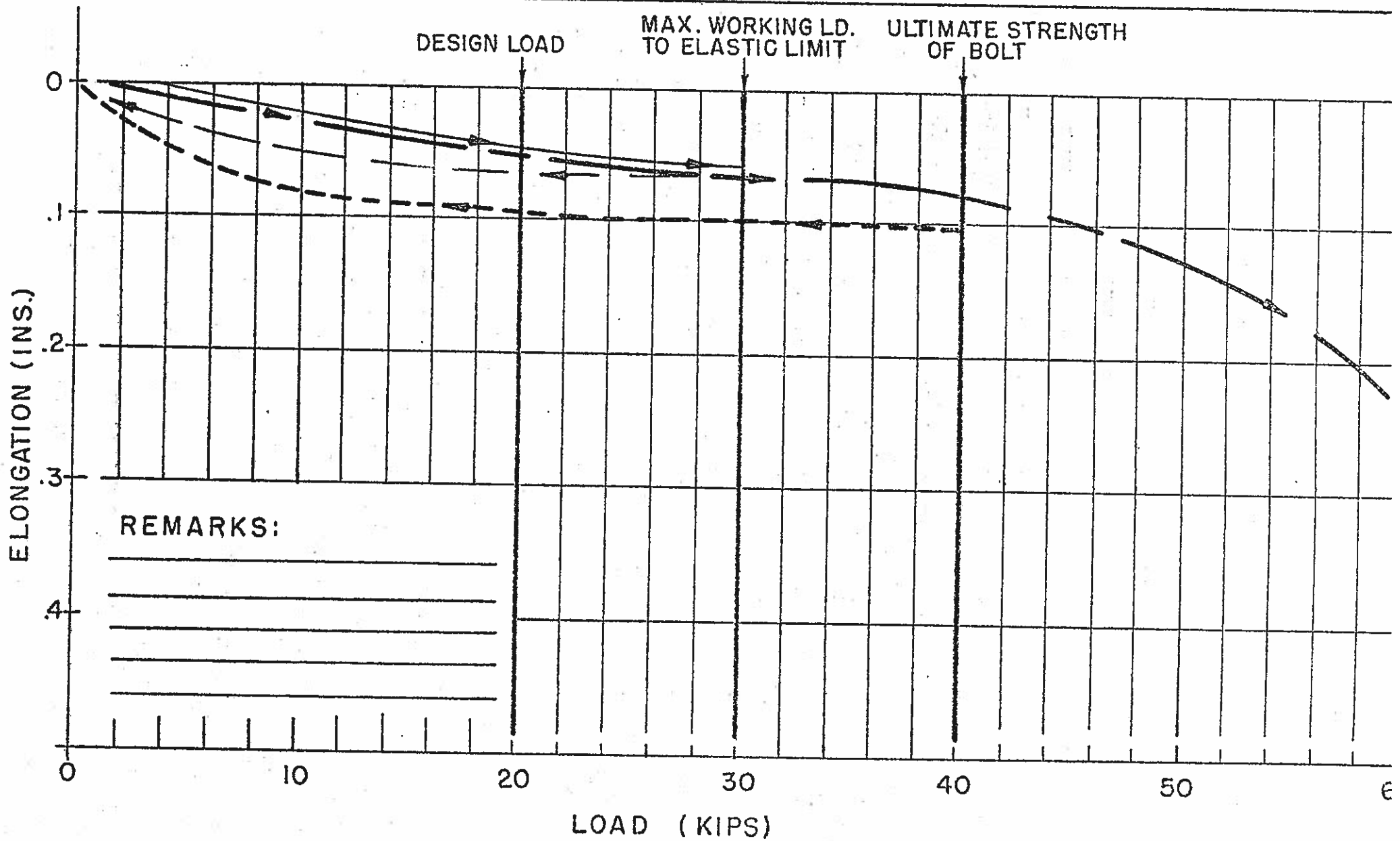
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



West PORTAL 51' Lt. Eb STA. 1777+25

ROCK BOLT NO. 1

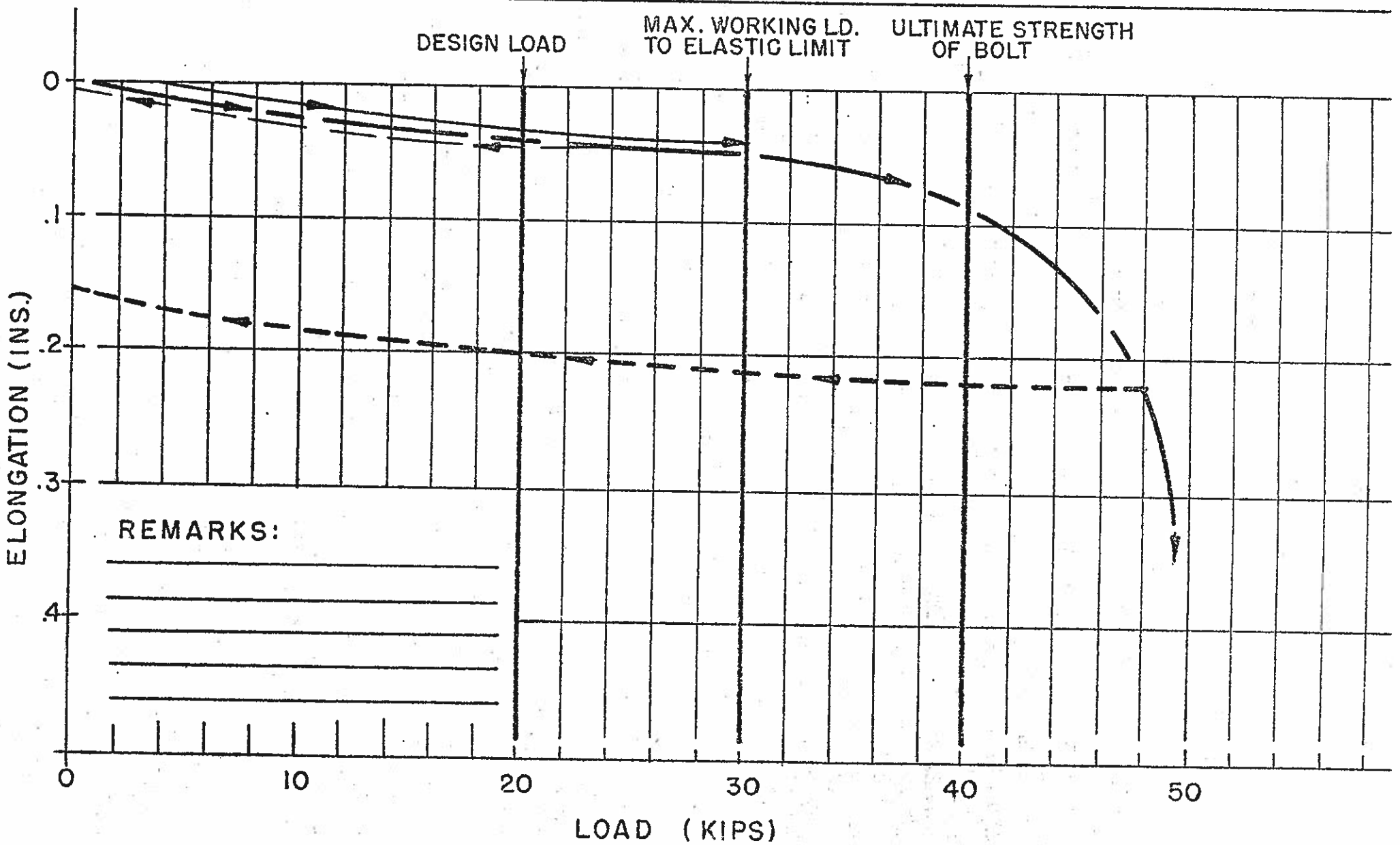
TORQUE ON BOLT TO EXPAND SHELL 140 FT.- LBS.



West PORTAL 42' Lt. Eb STA. 1777+25±

ROCK BOLT NO. 2

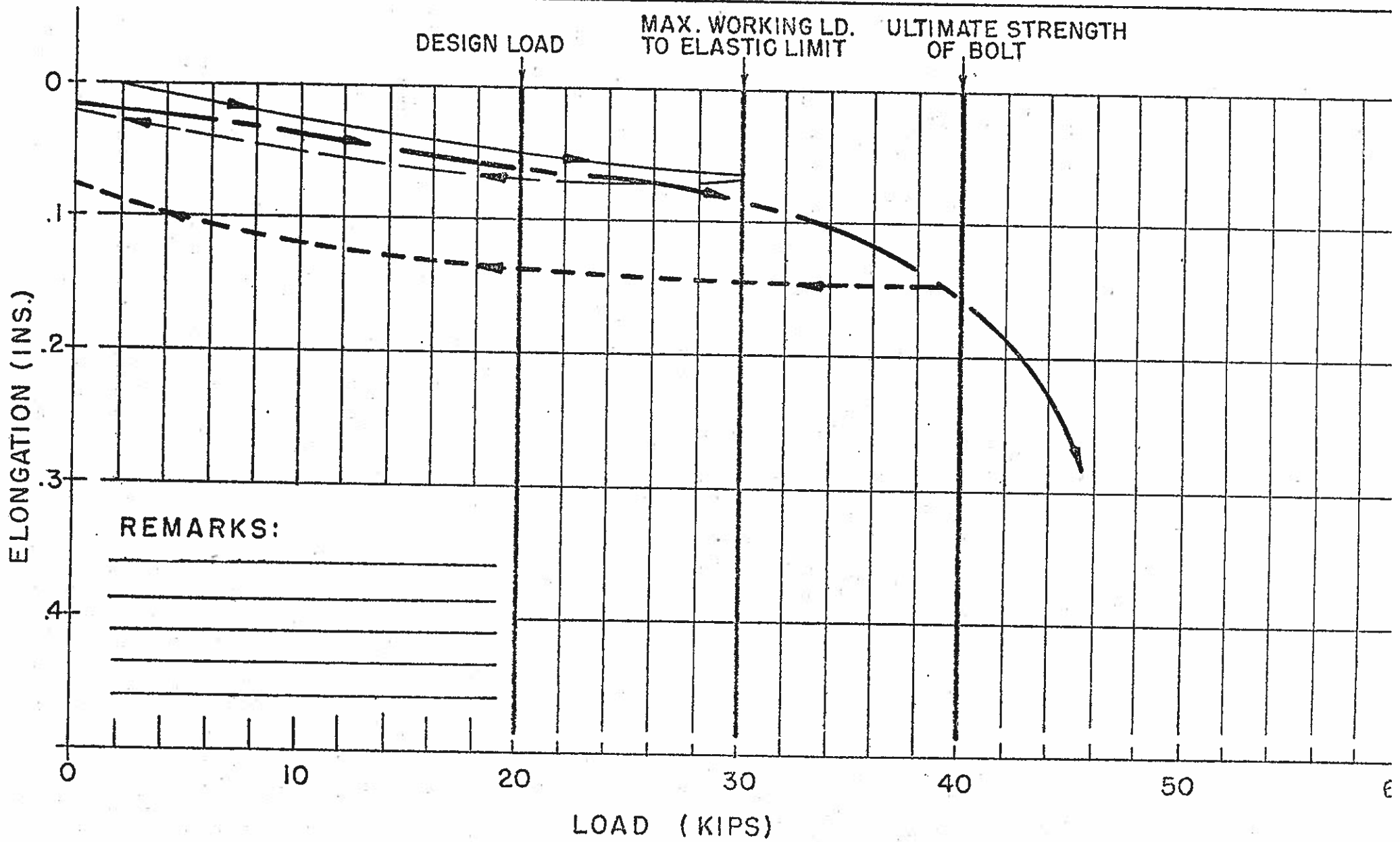
TORQUE ON BOLT TO EXPAND SHELL 210 FT.-LBS.



West PORTAL 25' Lt. Eb STA. 1777+25±

ROCK BOLT NO. 3

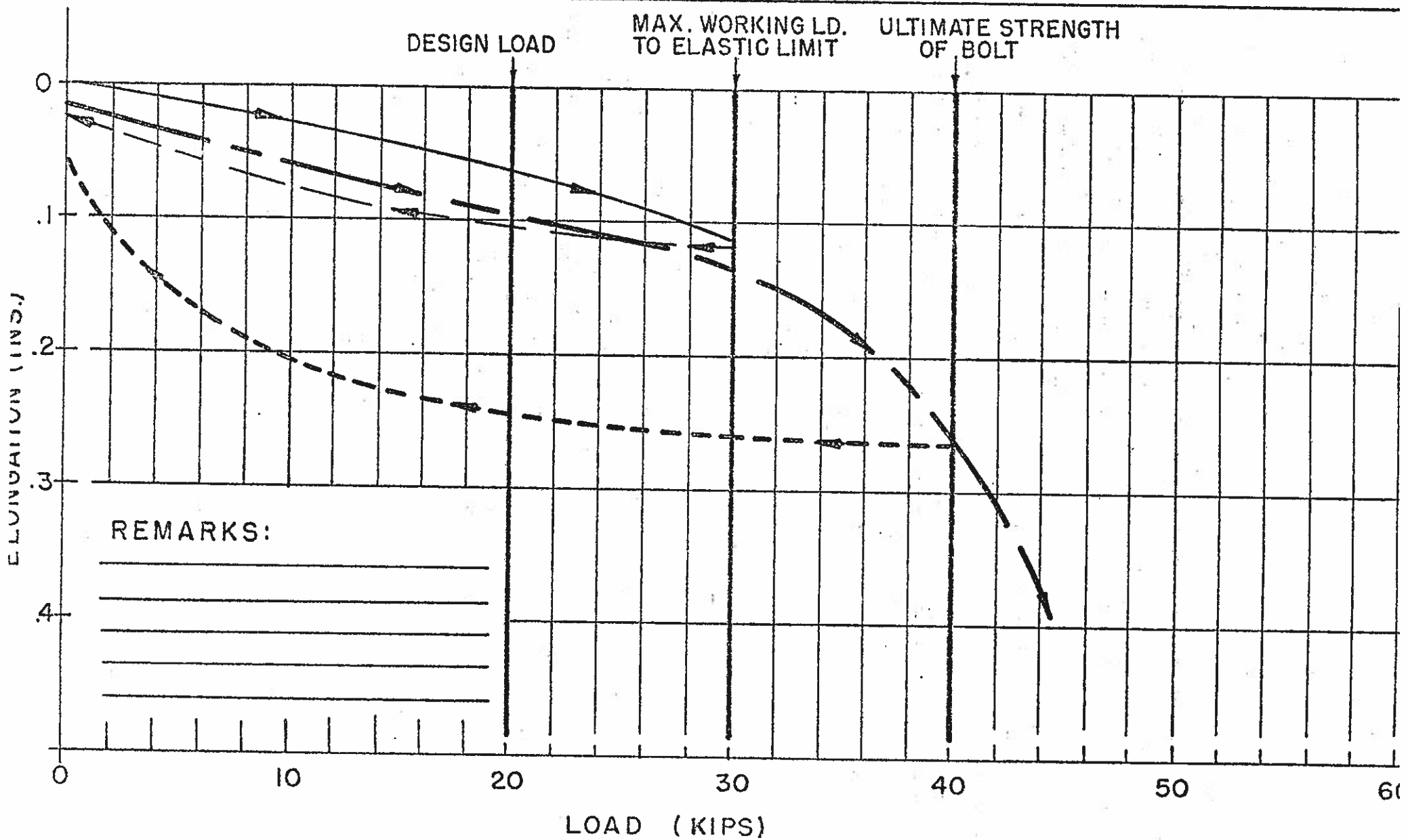
TORQUE ON BOLT TO EXPAND SHELL 240 FT.- LBS.



West PORTAL 51' Rt. Eb STA. 1777+25±

ROCK BOLT NO. 4

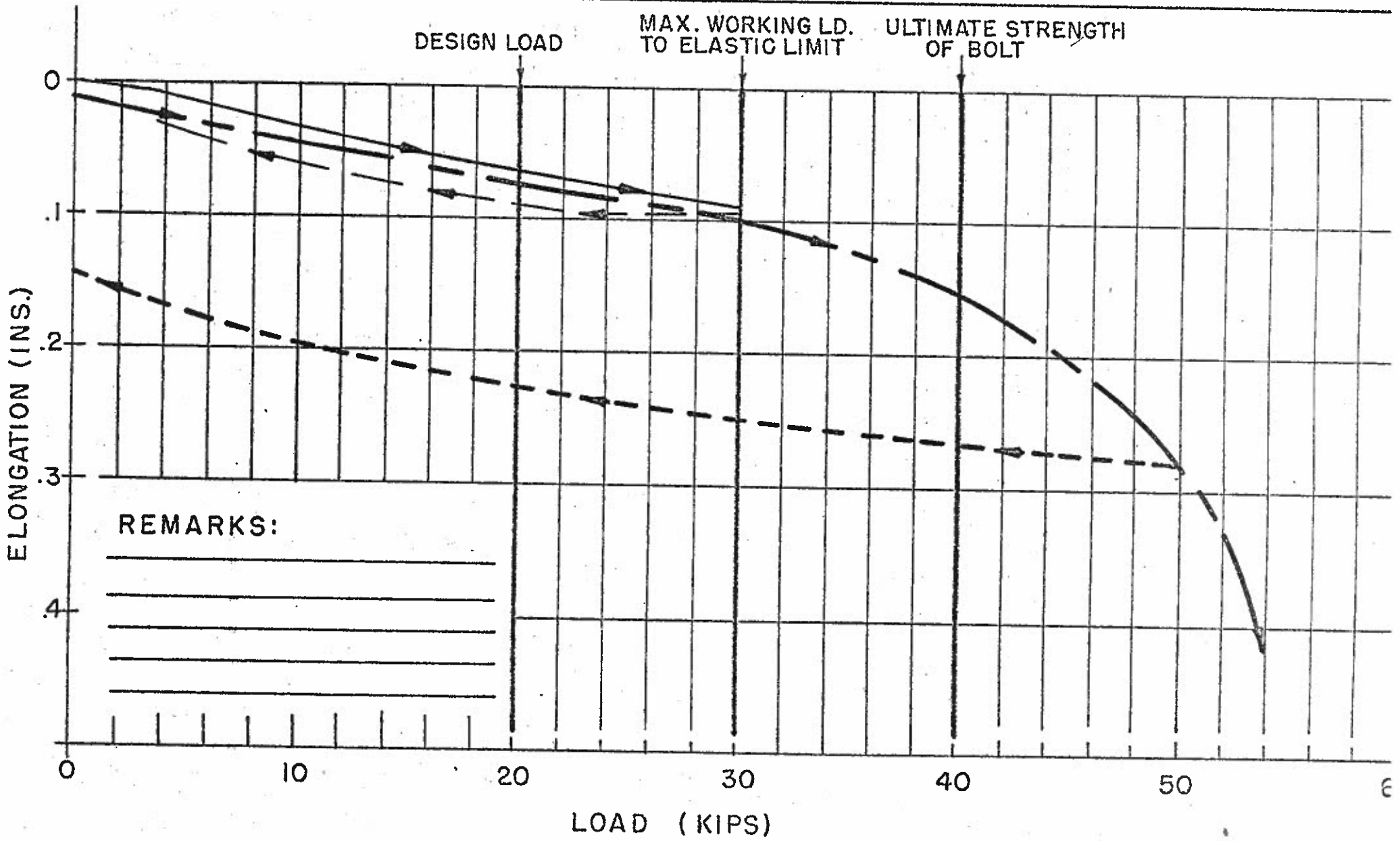
TORQUE ON BOLT TO EXPAND SHELL 240 FT.- LBS.



West PORTAL 80' Rt. Eb STA. 1777+25±

ROCK BOLT NO. 5

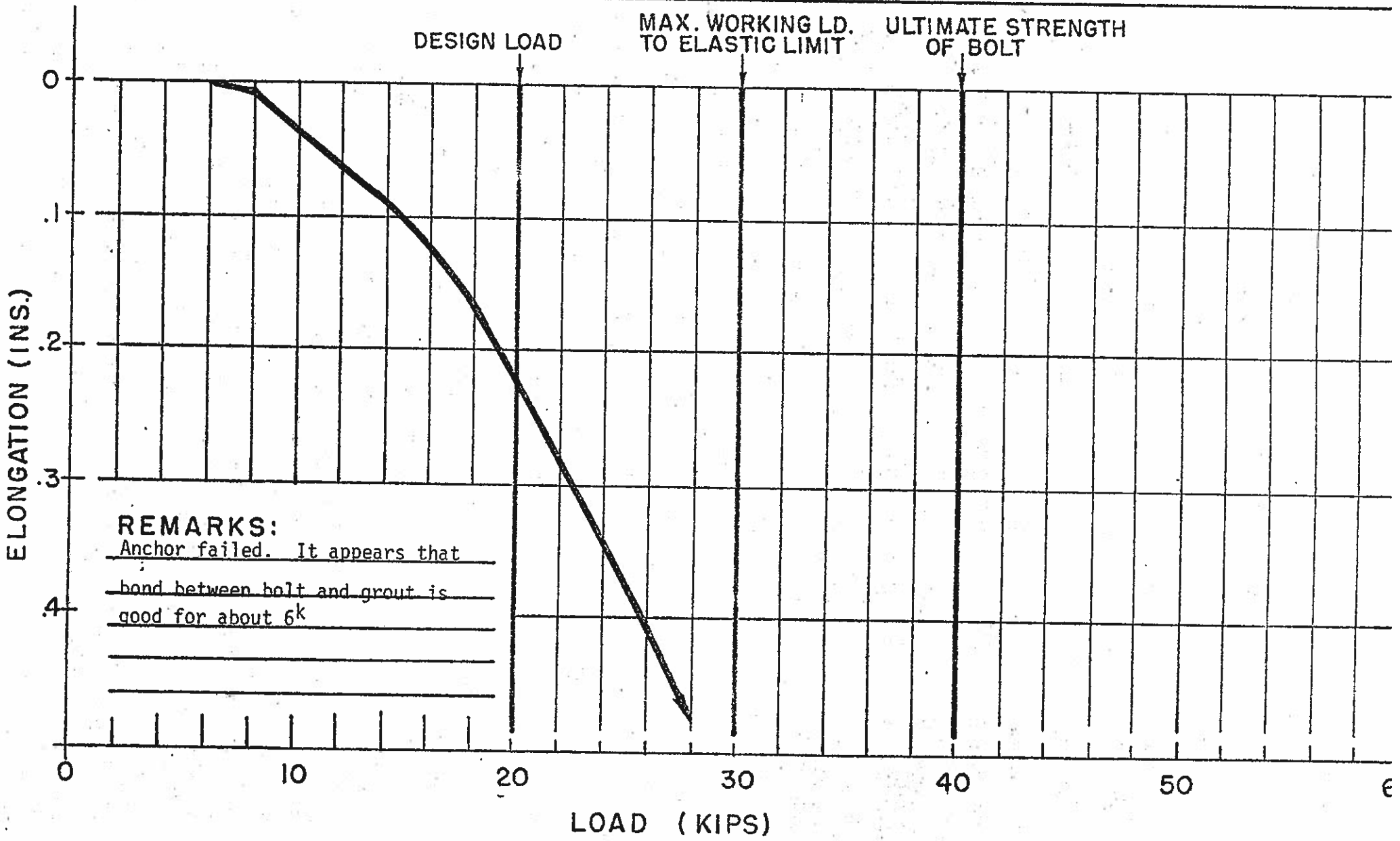
TORQUE ON BOLT TO EXPAND SHELL 260 FT.- LBS.



East PORTAL 50' Rt. Eb STA. 1792+

ROCK BOLT NO. 2

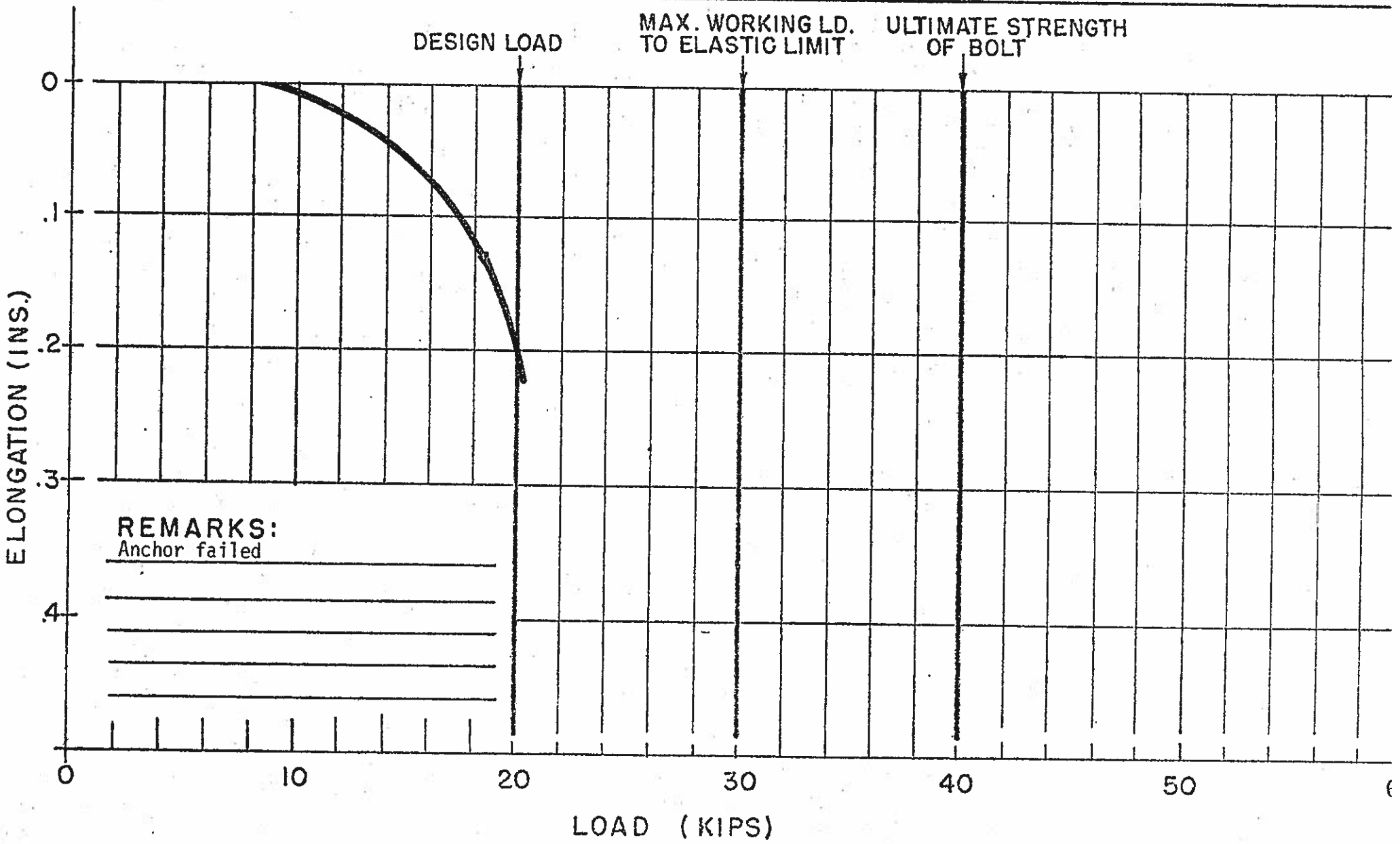
TORQUE ON BOLT TO EXPAND SHELL 195 FT.- LBS.



East PORTAL 24.5 Rt. Eb STA. 1792 ±

ROCK BOLT NO. 3

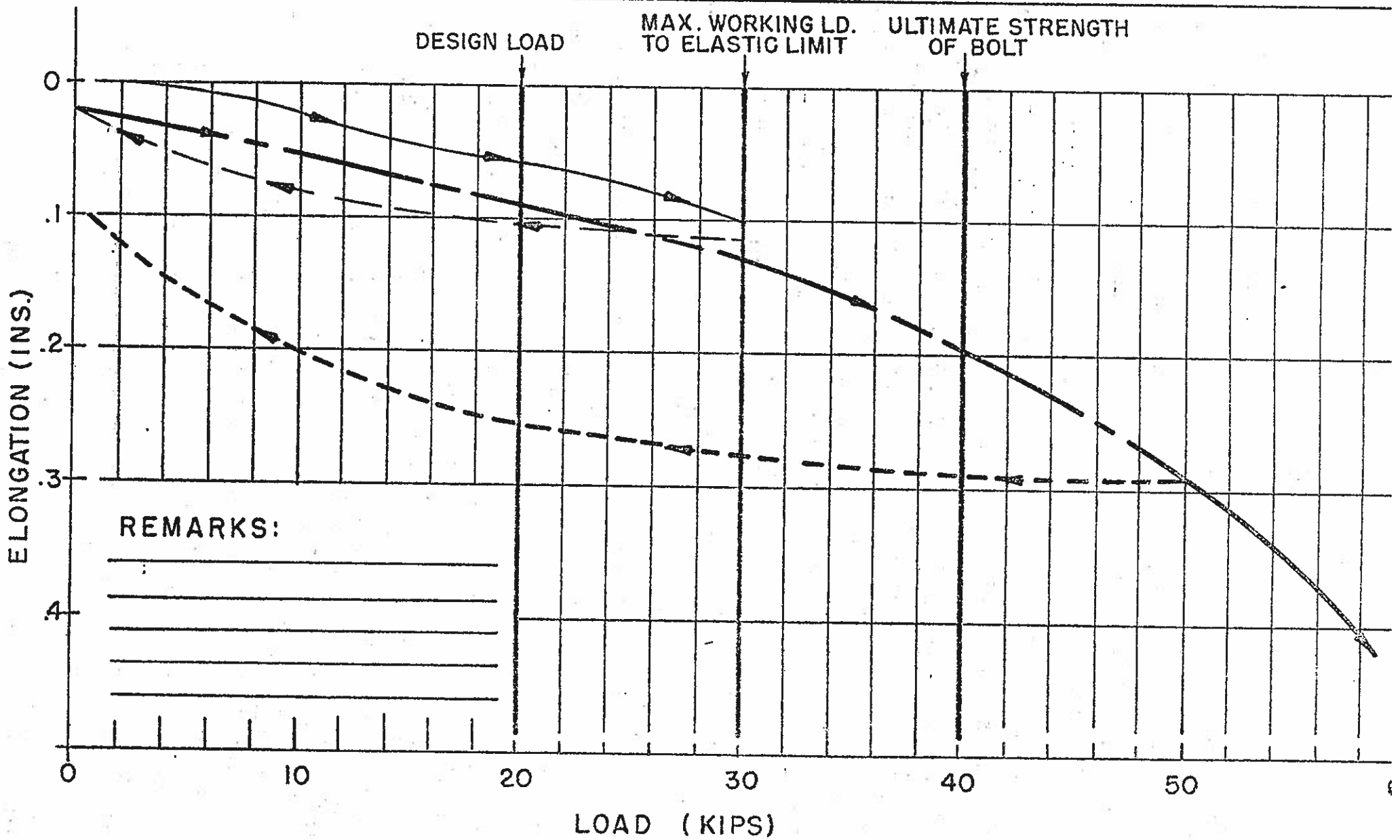
TORQUE ON BOLT TO EXPAND SHELL 260 FT.- LBS.



East PORTAL 26' Lt. Eb STA. 1792±

ROCK BOLT NO. 4

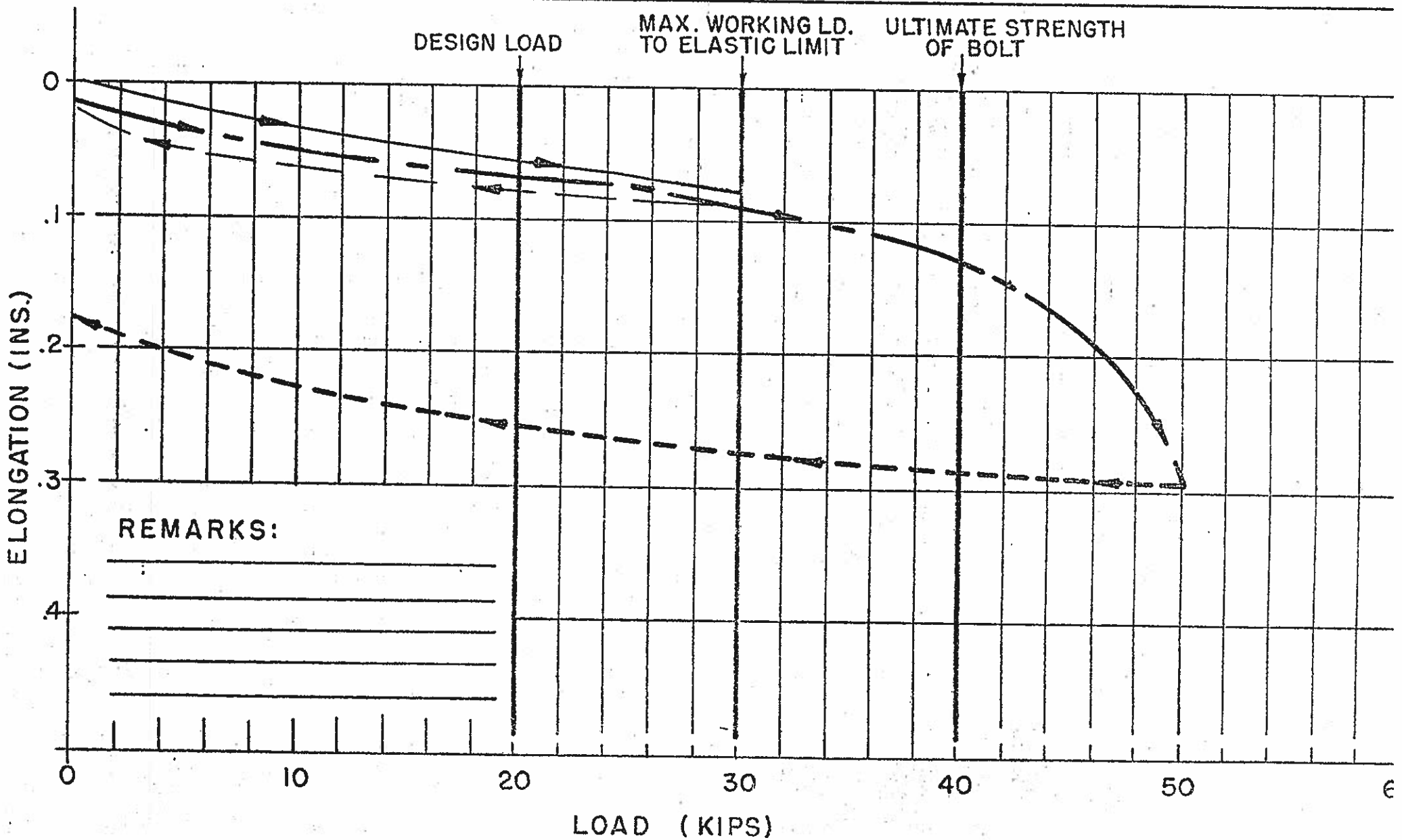
TORQUE ON BOLT TO EXPAND SHELL 240 FT.- LBS.



East PORTAL 42' Lt. Eb STA. 1792+

ROCK BOLT NO. 5

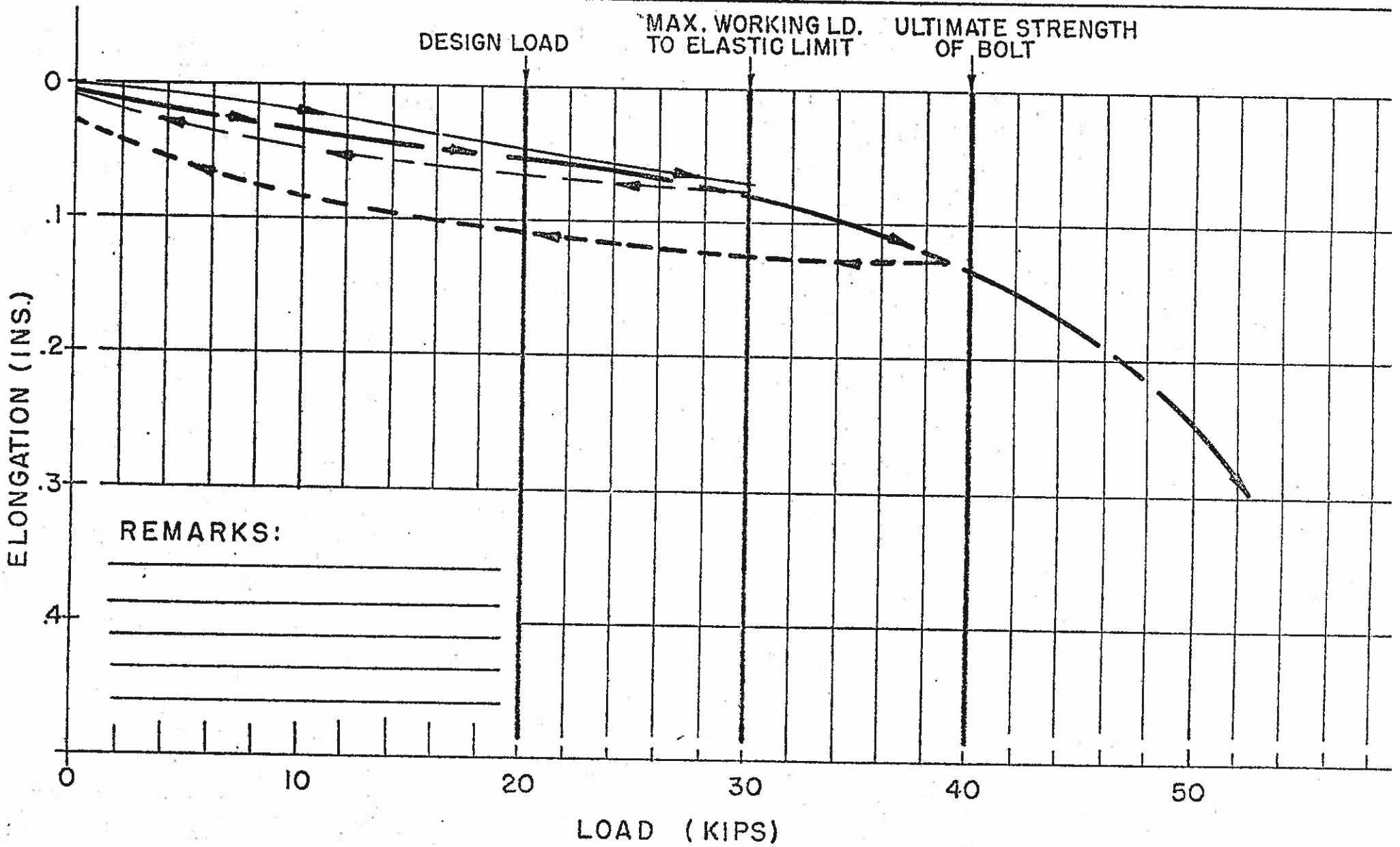
TORQUE ON BOLT TO EXPAND SHELL 240 FT.- LBS.



East PORTAL 57' Lt. Eb STA. 1792+

ROCK BOLT NO. 6

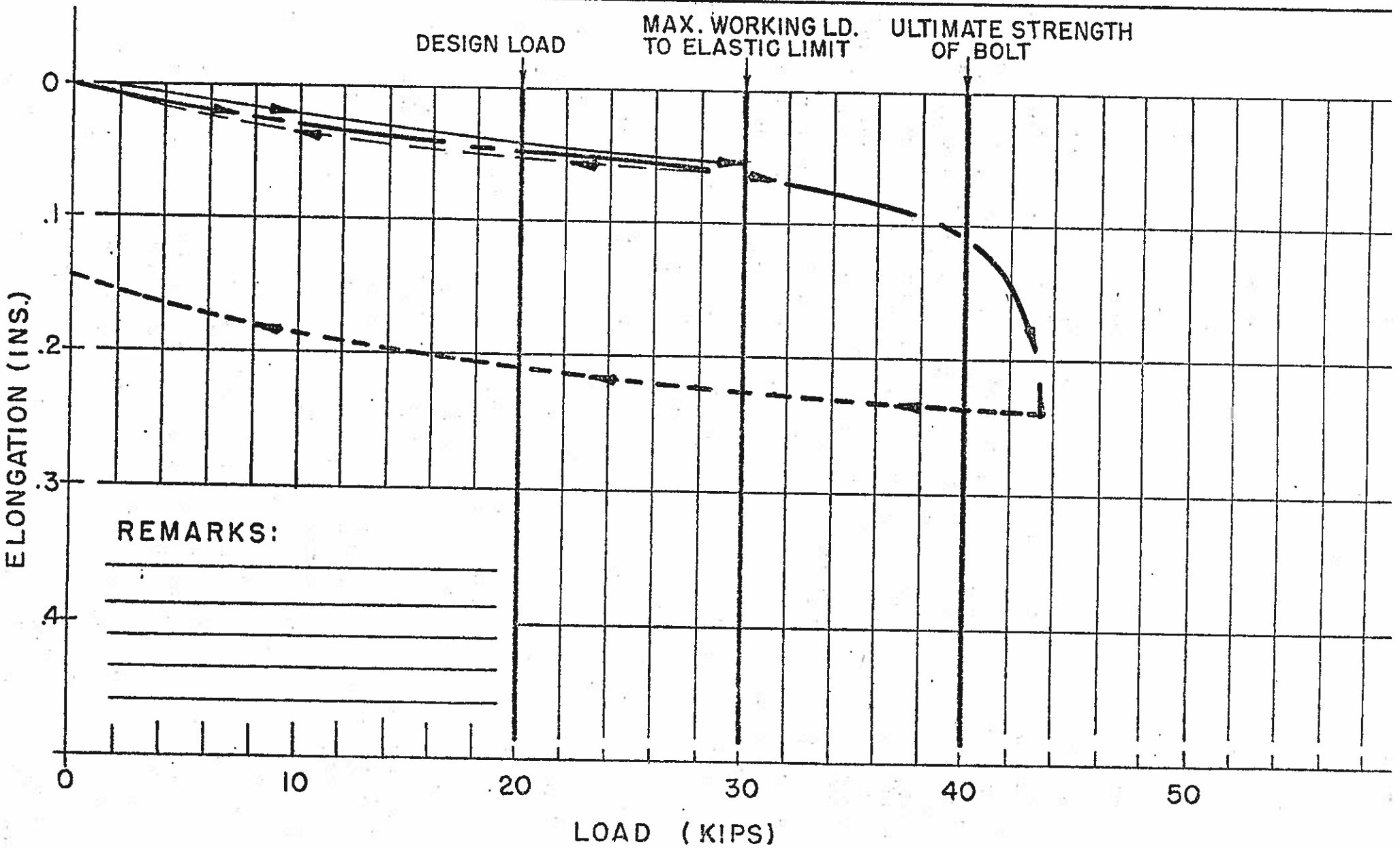
TORQUE ON BOLT TO EXPAND SHELL 240 FT.- LBS.



East PORTAL 108' Lt. Eb STA. 1792+

ROCK BOLT NO. 7

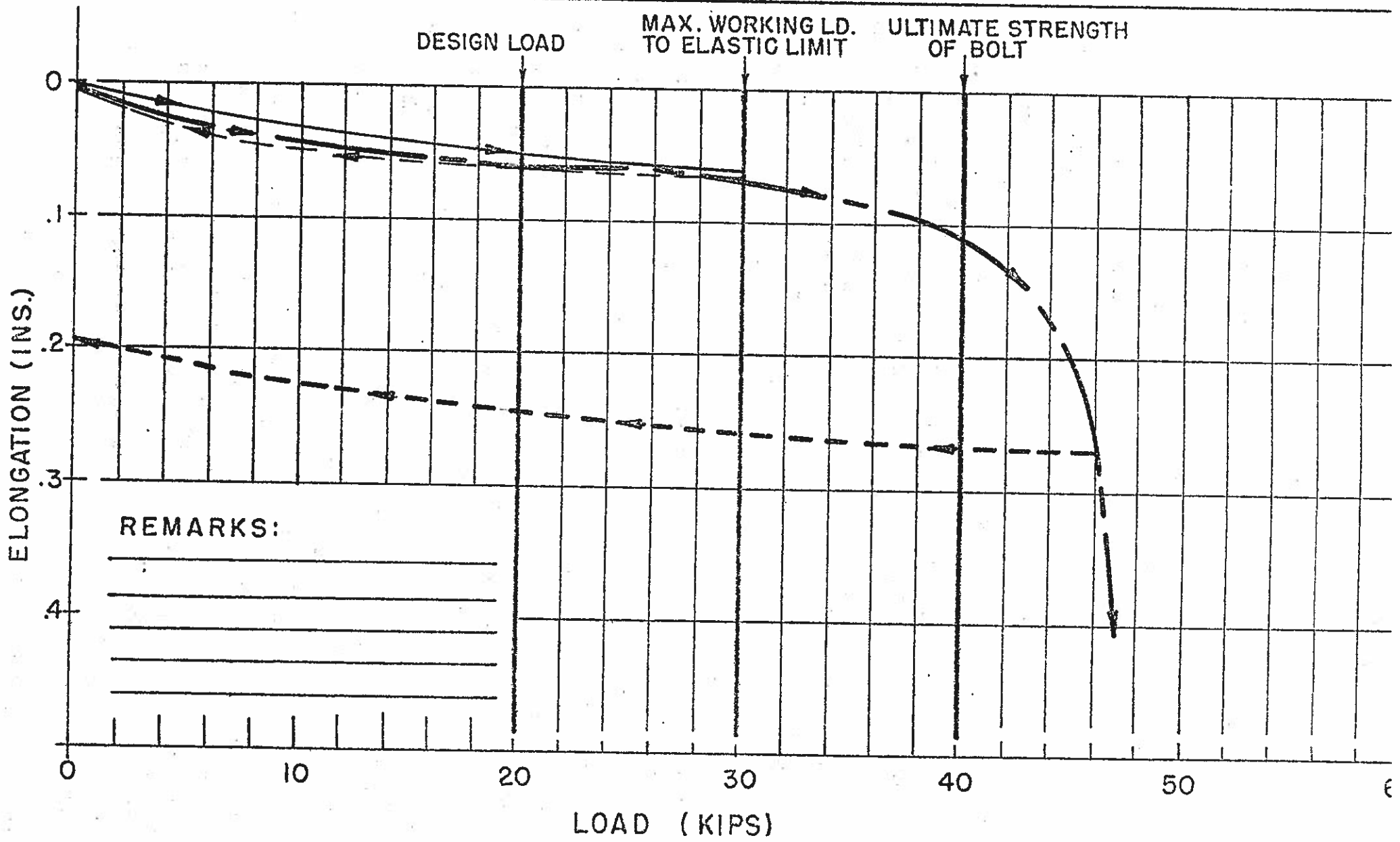
TORQUE ON BOLT TO EXPAND SHELL 240 FT.-LBS.



East PORTAL 133' Lt. Eb STA. 1792+

ROCK BOLT NO. 8

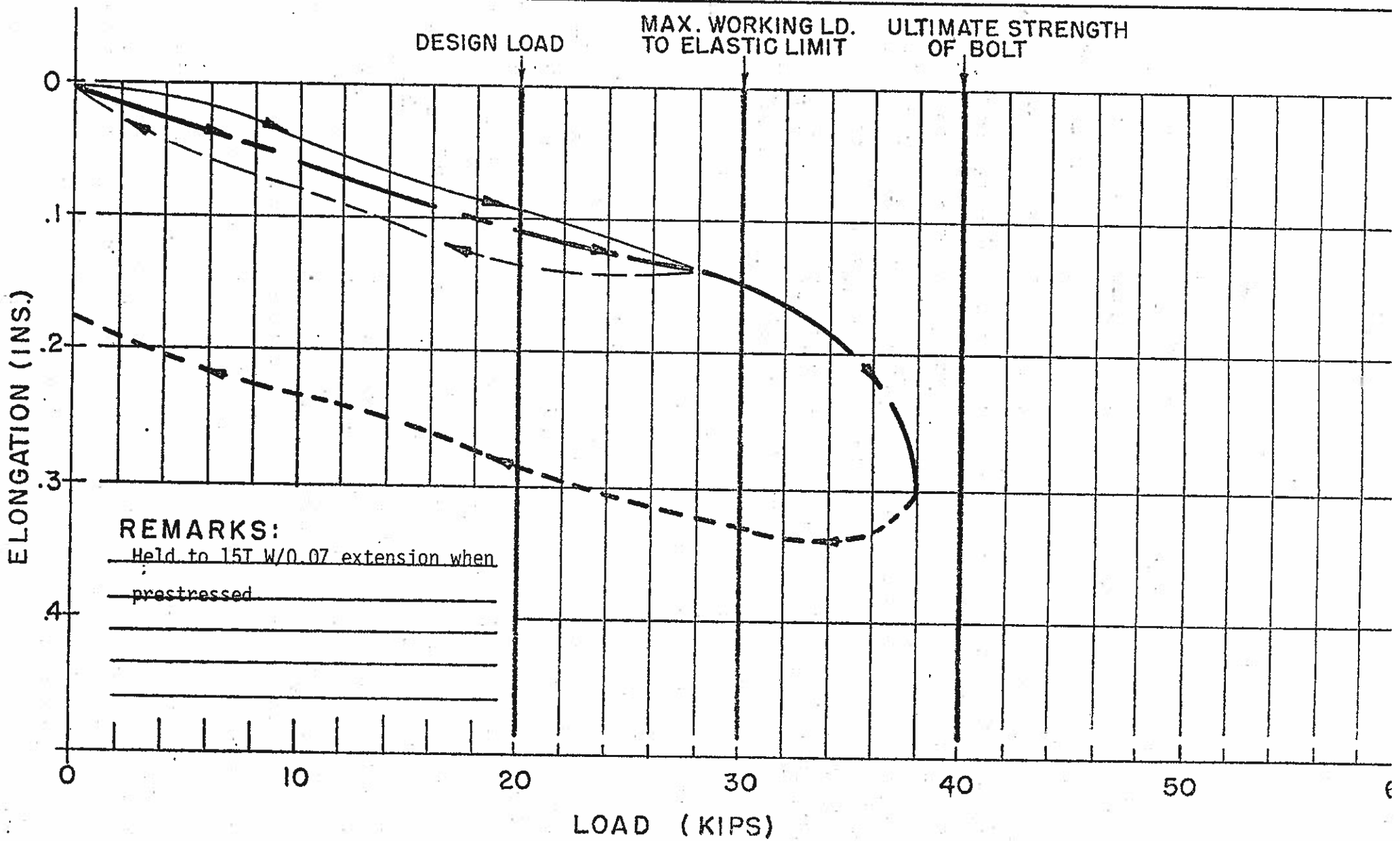
TORQUE ON BOLT TO EXPAND SHELL 260 FT.-LBS.



East PORTAL 50' Rt. Fb STA. 1792+

ROCK BOLT NO. 2A

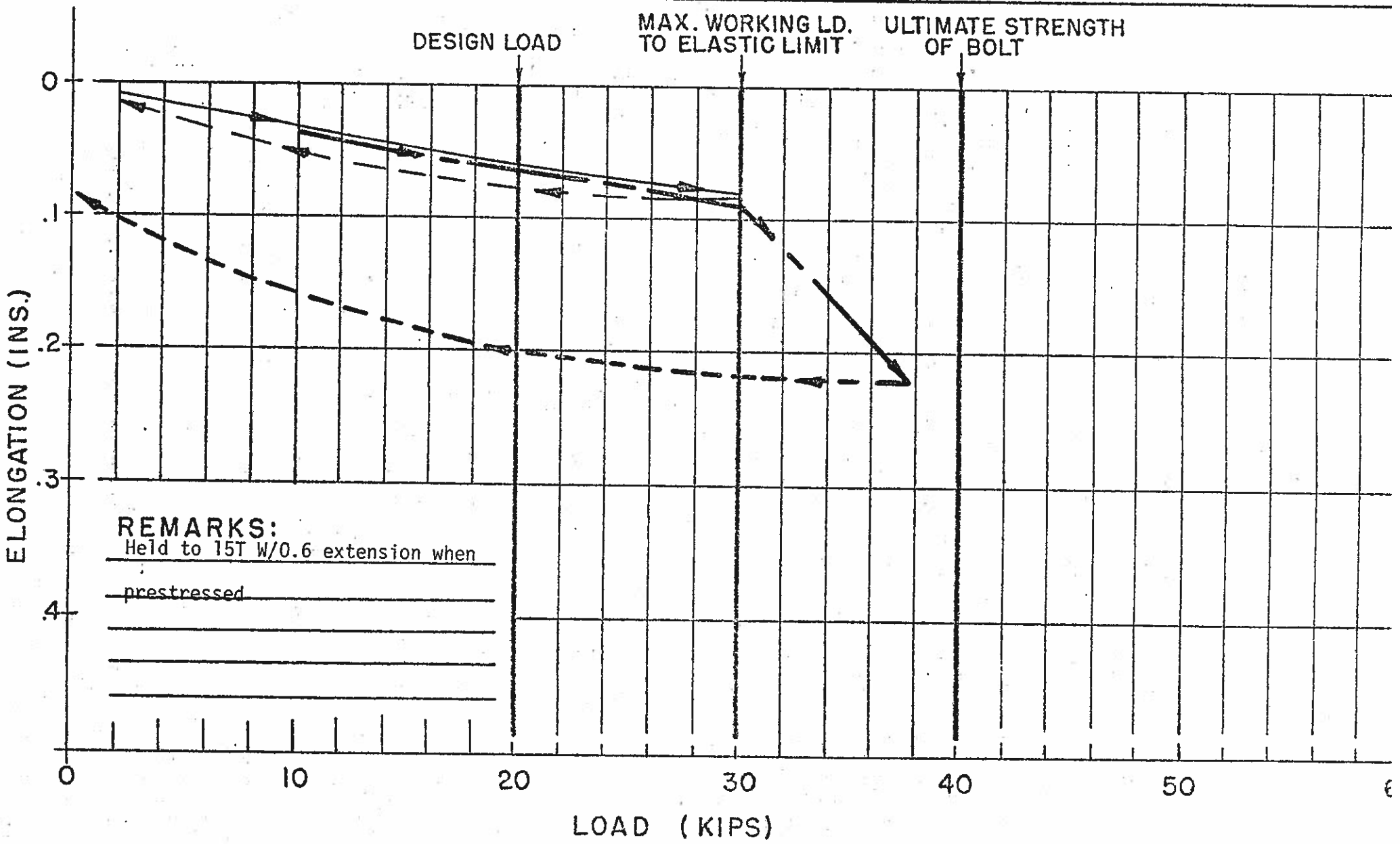
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



▲ East PORTAL 30' Lt. Eb STA. 1792+

ROCK BOLT NO. 4A

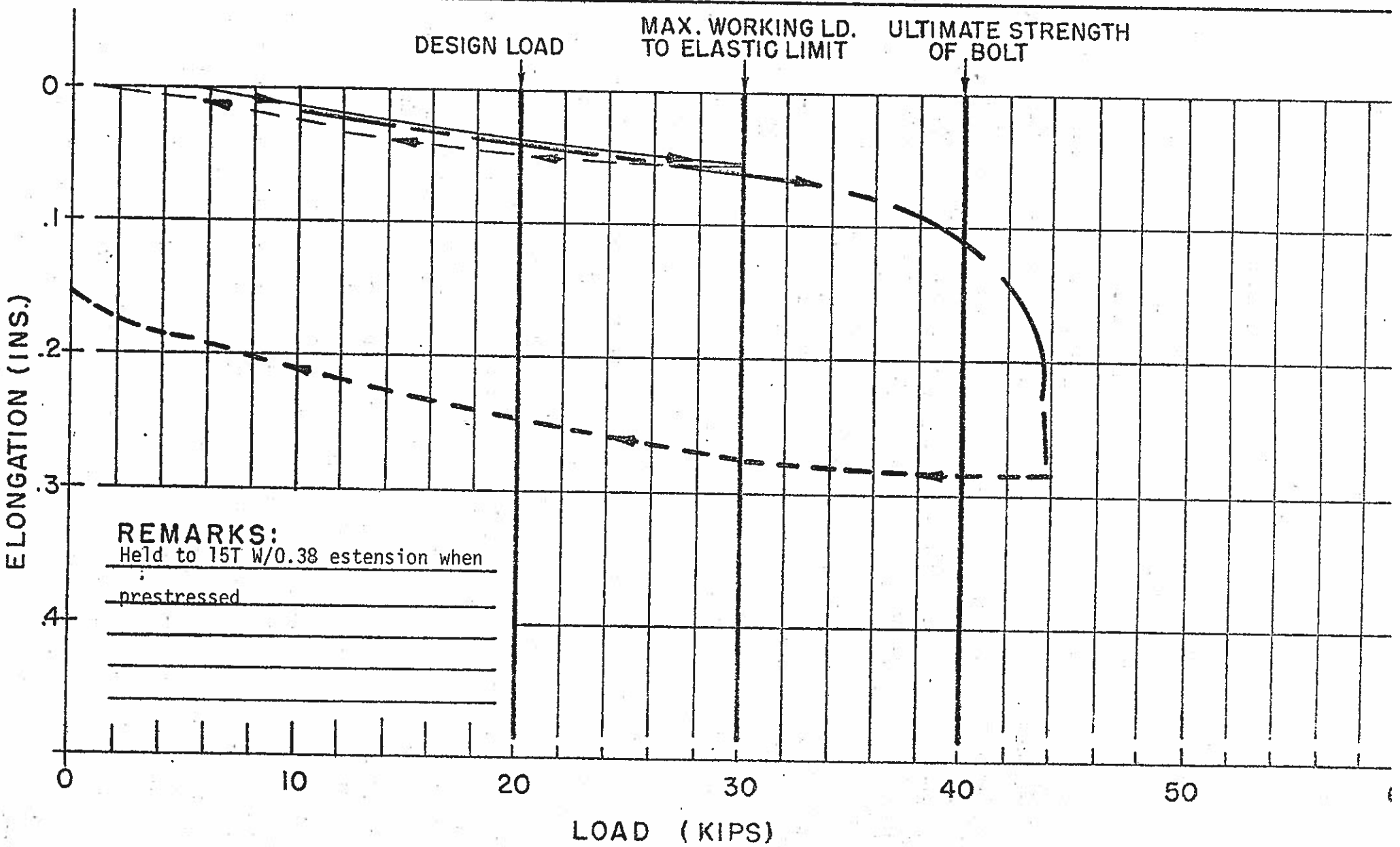
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



▲ East PORTAL 50' Lt. Eb STA. 1792+

ROCK BOLT NO. 5A

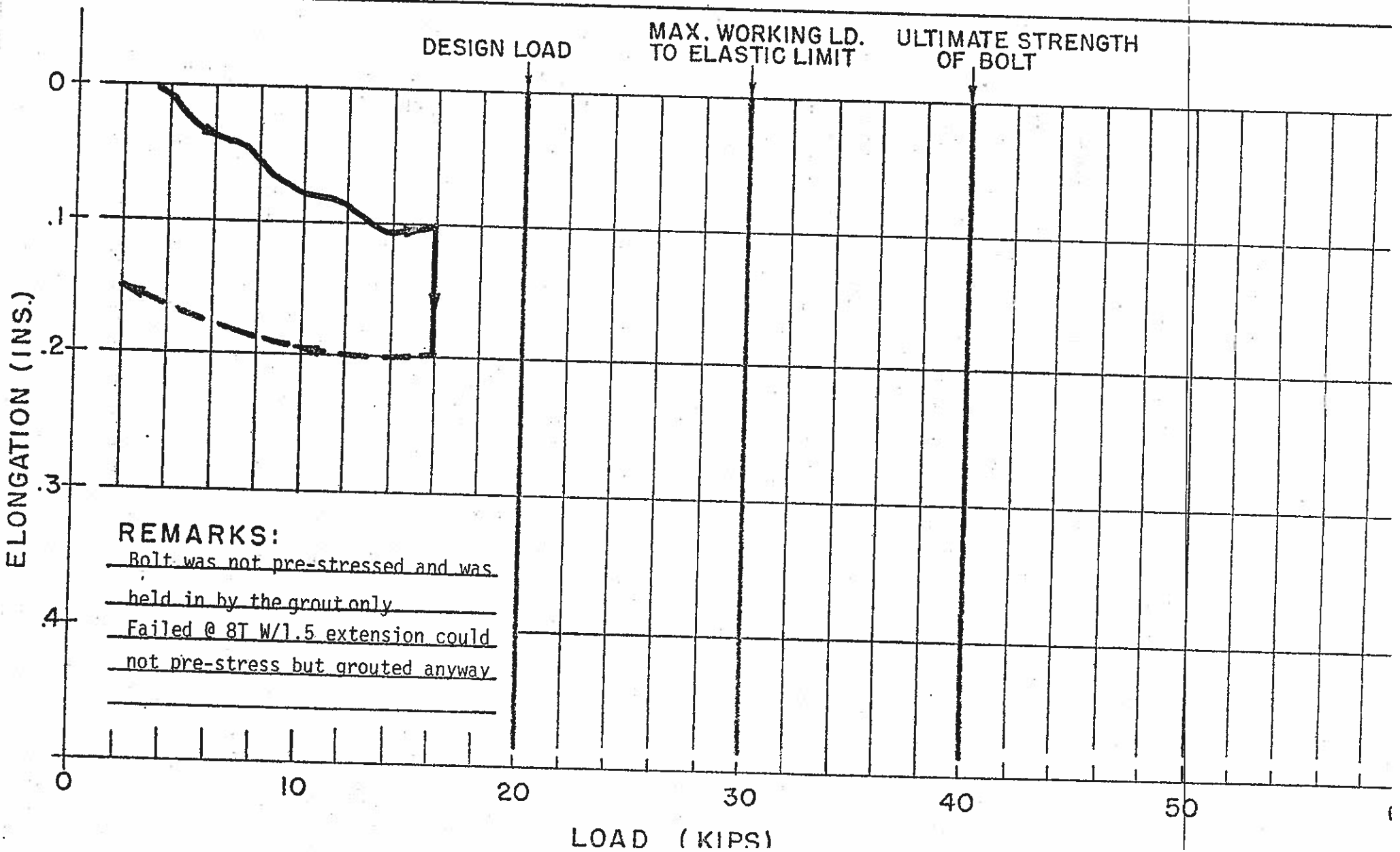
TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.



East PORTAL 87' Lt. Eb STA. 1792+

ROCK BOLT NO. 6A

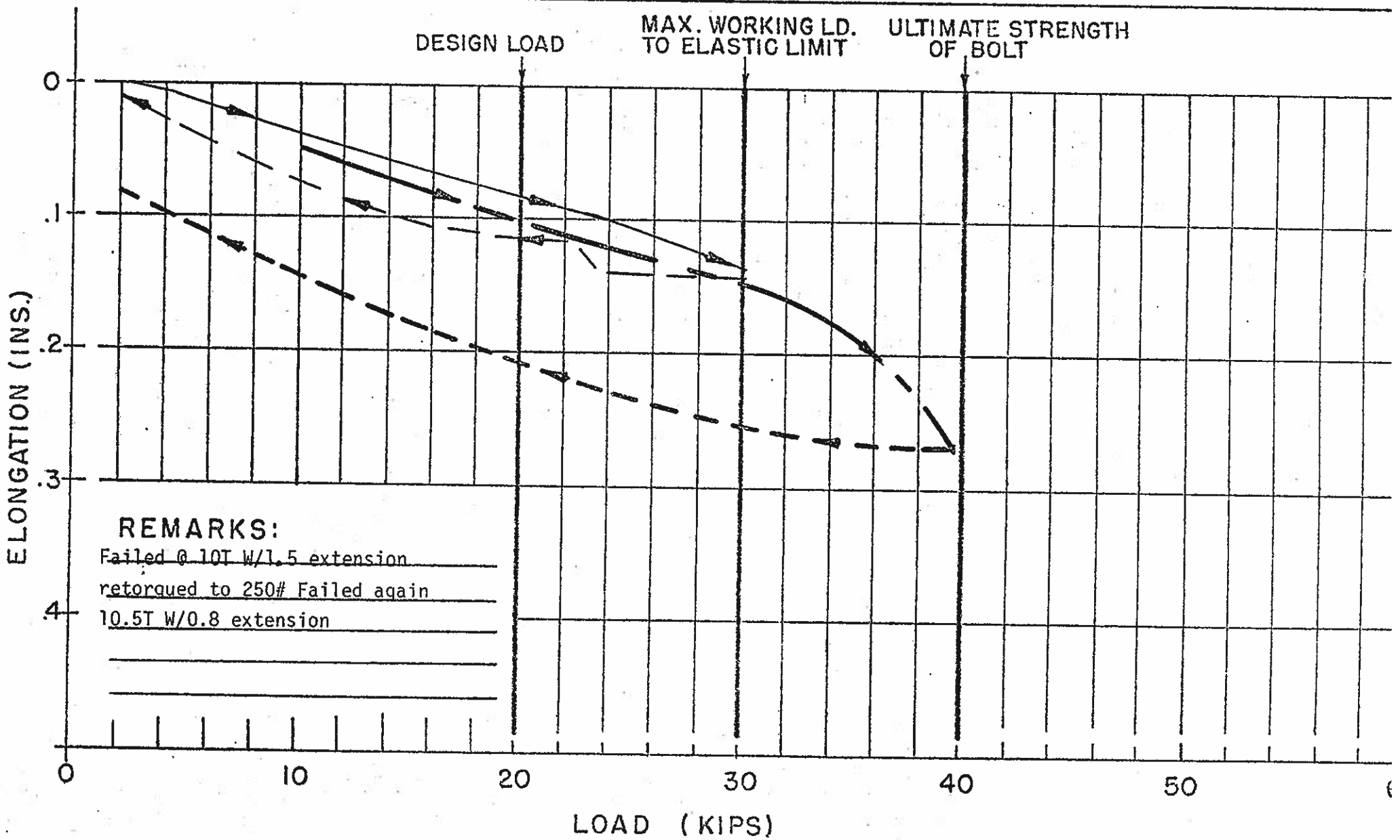
TORQUE ON BOLT TO EXPAND SHELL 0 FT.- LBS.



▲ East PORTAL 100' Lt. Fb STA. 1792+

ROCK BOLT NO. 7A

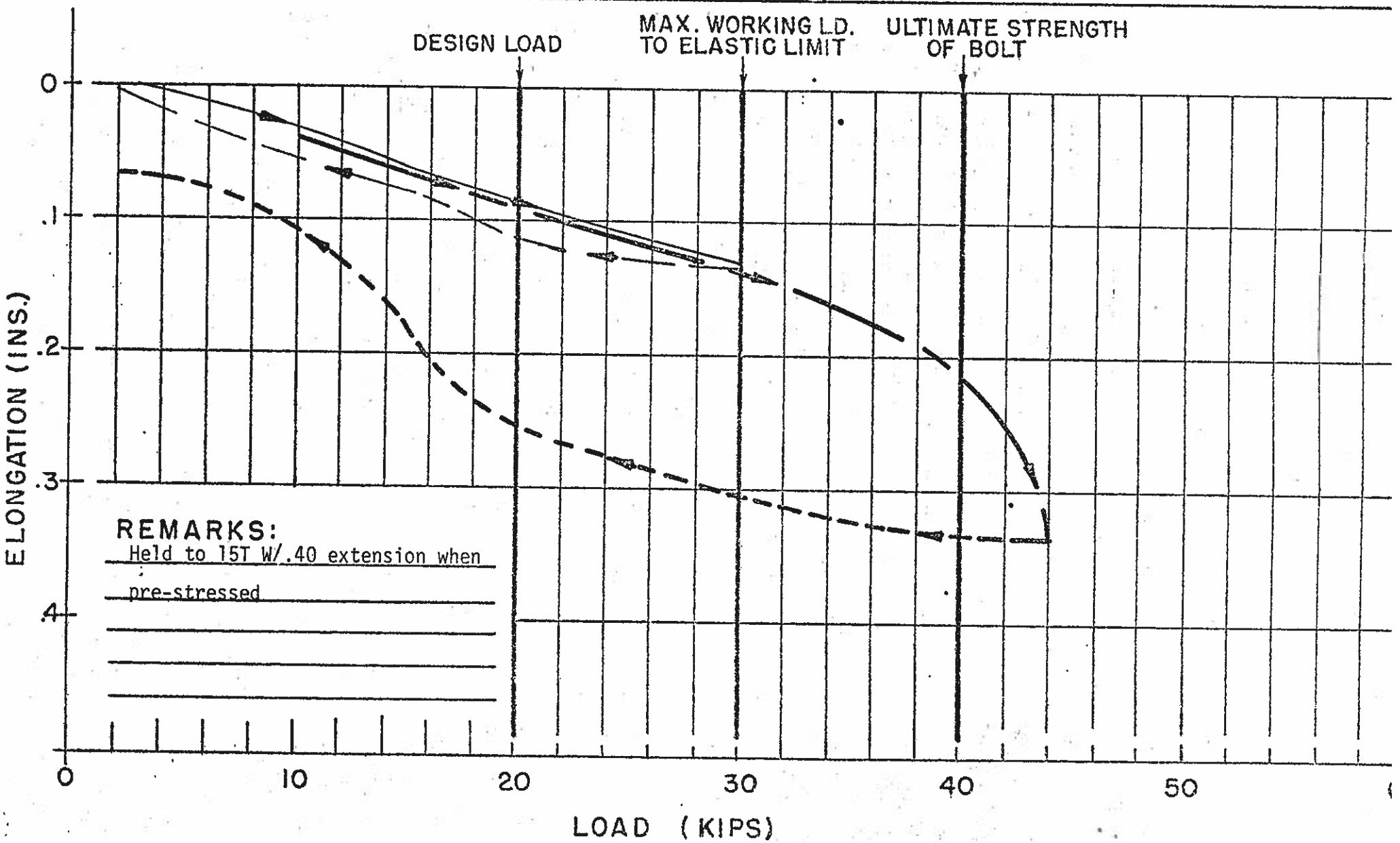
TORQUE ON BOLT TO EXPAND SHELL 250 FT.-LBS.



▲ East PORTAL 137' Lt. Fb STA. 1792+

ROCK BOLT NO. 8A

TORQUE ON BOLT TO EXPAND SHELL 250 FT.-LBS.



East PORTAL 152' Lt. Eb STA. 1792+

ROCK BOLT NO. 9A

TORQUE ON BOLT TO EXPAND SHELL 250 FT.- LBS.