Engineering Standard

SAES-L-460 10 November 2012

Pipeline Crossings under Roads and Railroads

Document Responsibility: Piping Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

1.1 This standard defines the minimum design and installation requirements governing pipeline crossings under roads, parking lots, railroads, and airport runways.

1.2 This standard applies to pipelines in all services.

1.3 This standard supplements the latest edition of API RP 1102 "Steel Pipelines Crossing Railroads and Highways."

1.4 Additional requirements imposed by the Saudi Arabian Government shall apply to crossings of Government roads and railroads.

2 Conflicts and Deviations

2.1 Any conflicts between this standard and other applicable Saudi Aramco Engineering Standards (SAESs), Materials System Specifications (SAMSSs), Standard Drawings (SASDs), or industry standards, codes, and forms shall be resolved in writing by the Company or Buyer Representative through the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

2.2 Direct all requests to deviate from this standard in writing to the Company or Buyer Representative, who shall follow internal company procedure SAEP-302 and forward such requests to the Manager, Consulting Services Department of Saudi Aramco, Dhahran.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below, unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302	*Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standards

SAES-A-114	*Excavation and Backfill*
SAES-H-002	*Internal and External Coatings for Steel Pipelines and Piping*

SAES-L-150	*Pressure Testing of Plant Piping and Pipelines*
SAES-L-410	*Design of Pipelines*
SAES-L-440	*Anchors for Buried Pipelines*
SAES-L-450	*Construction of on-Land and Near-Shore Pipelines*
SAES-L-470	*Trenchless Pipelines Construction Requirements*
SAES-L-610	*Non-Metallic Piping in Oily water services*
SAES-L-650	*Construction of Nonmetallic Piping in Hydrocarbon and Water Injection Systems*
SAES-Q-001	*Criteria for Design and Construction of Concrete Structures*
SAES-Q-006	*Asphalt Concrete Paving*
SAES-S-070	*Installation of Utility Piping Systems*
SAES-W-011	*Welding Requirements for On-Plot Piping*
SAES-W-012	*Welding Requirements for Pipelines*
SAES-X-400	*Cathodic Protection of Buried Pipelines*

Saudi Aramco Standard Drawing

AB-036255	*Plan and Detail Concrete Slabs for Road Crossing*
AB-036660	*Road Crossings For Pipelines*
AB-036880	*Sleeved Crossing For Restrained Pipelines*

Saudi Aramco Engineering Report

SAER-6078	*Analysis & Design of Buried Pipelines*

Saudi Aramco General Instructions

GI-1021.000	*Street and Road Closure: Excavation, Reinstatement and Traffic Controls*

3.2 Industry Codes and Standards

American Petroleum Institute

API RP 1102	*Steel Pipelines Crossing Railroads and Highways*

American Society for Testing and Materials

ASTM E515	*Testing for Leaks Using Bubble Emission Techniques*

American Water Works Associations

AWWA M45 *Fiberglass Pipe Design*

American Railway Engineering Association

4 Definitions

Camel Crossing: Minor road crossing of aboveground or bermed pipelines that are needed to provide passage of grazing herds and light vehicles.

Carrier Pipe: The pipe used for transporting liquids or gas.

Casing: The pipe through which the carrier pipe is installed.

Depth of Cover: The height of the soil measured from the crown of the carrier pipe or casing to the road surface.

Road: Any paved or unpaved passageway or track that may be used by any vehicular traffic, including shoulders or strips adjacent to the pavement where cars may be parked and other designated parking areas.

Wheel Load: the load applied by the vehicle axial distributed on wheels.

Tire Load: External load applied by the wheel at the surface of the crossing.

Traffic Load Classifications: The following traffic load classifications can be used by Saudi Aramco:

AR-2: Roads on which vehicles heavier than 2 metric tons are prohibited. The design wheel load (i.e., basic wheel load) is 0.8 metric ton. AR-2 applies mostly to patrol roads along security fences, some roads and parking lots in plants and residential areas and to unpaved camel crossings.

AR-10: Roads on which trucks are limited to 10 metric tons except on very rare occasions. The design wheel load is 4 metric tons. AR-10 applies mostly to main roads in plants and residential areas, and to unpaved camel crossings.

AR-20: Roads which are frequently used by heavy cranes and tanker trailers in industrial areas. The design wheel load is 7 metric tons. AR-20 applies mostly to major roads in shipping terminals.

AR-40: Loads which are frequently used by 40 metric ton trucks. The design wheel load is 9 metric tons. AR-40 applies to main thoroughfares and government highways.

AR-300: Designated crossings used by the 300 metric ton drilling platform. The design wheel loading is 60 metric tons applied on 2 loaded areas at 3.8 m centers.

B737: Saudi Aramco airport runways. Loading is based on two 49-metric-ton landing wheel sets for a Boeing 737.

E-72: Railroads per the American Railway Engineering Association. Loading is based on three cross ties each carrying 65 metric tons (72 short tons).

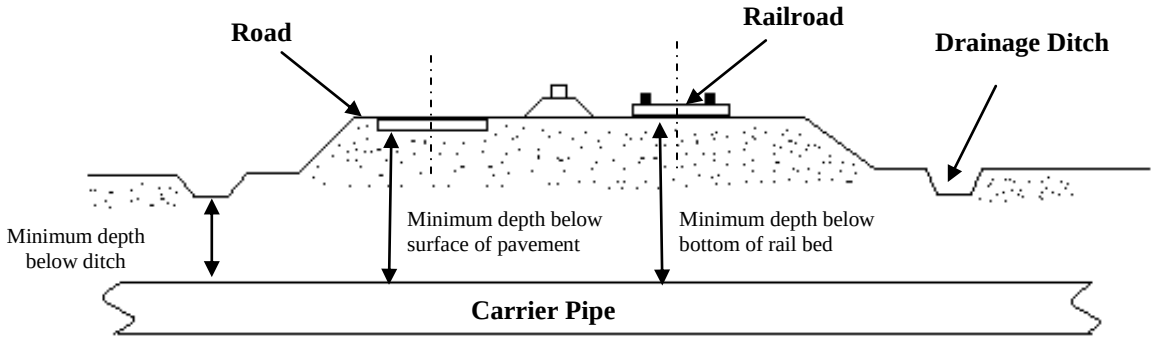
5 Approval of Crossings

The location of all proposed pipeline crossings outside Saudi Aramco facilities shall be reviewed by the Facilities Planning Department to determine its jurisdiction. Crossings of Saudi Aramco roads shall be coordinated with the Roads and Wellsites Division prior to construction. Crossings of Government roads, highways and railroads shall be coordinated with the Government Affairs Department for proper authorization prior to construction.

6 Crossing Design Criteria

6.1 Except for crossings with concrete slabs, concrete encasement, bridges, or culverts, the minimum cover over carrier steel pipe or steel casing shall be in accordance with Table 1.

Table 1 – Minimum Cover for Pipeline Crossings Under Railroads and Highways



	Minimum Cover (1)	
Railroad Crossings Location	**Cased**	**Uncased**
Under track structure proper, except secondary and industry track	1.7 m	(3)
Under track structure proper for secondary and industry track	1.4 m	(3)
Under all other surfaces within the right-of-way or from bottom of ditches	0.9 m	(3)
For pipelines transporting highly volatile liquid (HVL)	1.2 m	(3)

	Minimum Cover (2)	
Highway Crossings Location	**Cased**	**Uncased**
Under highway surface proper	1.2 m	1.2 m
Under all other surfaces within the right-of-way or from the bottom of ditches	0.9 m	0.9 m
For pipelines transporting highly volatile liquid (HVL) (4)	1.2 m	1.2 m

Notes:

(1) Measured from the top of the casing pipe to the base of the rail.

(2) Measured from the top of the pipe to the bottom of the final finished ground surface, such as asphalt road surface.

(3) Uncased crossings under railroads are not permitted. See paragraph 6.3.

(4) For the purpose of this standard, HVL is a hazardous liquid that will form a vapor cloud when released to the atmosphere and that has a vapor pressure exceeding 276 kPa (40 psia) at 37.8°C.

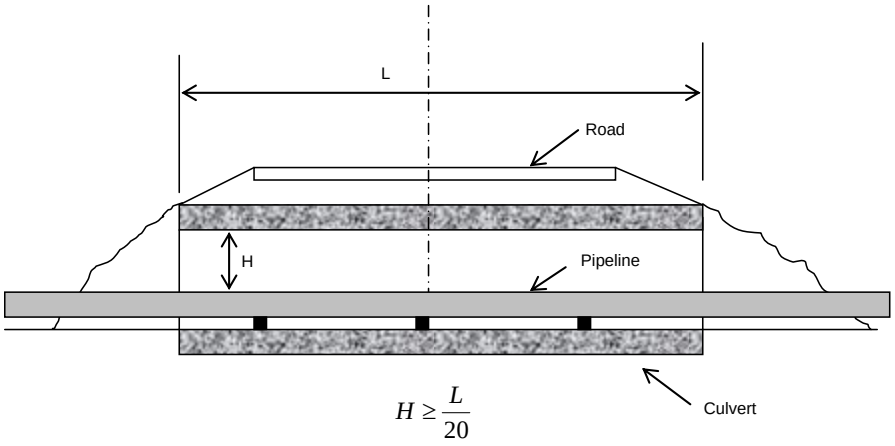
6.2 For road crossings of new pipelines as well as existing pipelines under rehabilitation and provided that the stresses are within the acceptable limits as per paragraph 7, carrier pipes without casings shall be used as the normal installation method at crossings.

6.3 Casings for pipelines under construction shall be used for all railroad crossings. For existing pipelines, the railroad crossings design shall be approved by the Consulting Services Department and the operating organization.

Commentary Note:

The intent of this requirement is not only to protect the pipelines from the rail road loads, but also to avoid any damage to the rail road when gas leaks or oil spillage occurs. The rail road is considered source of ignition and all safety measures shall be considered during the design.

6.4 The maintenance access requirement for the carrier pipe under bridge or inside culvert shall provide a safe working environment. The clearance between the top of the pipeline and the culvert ceiling or the bridge beams shall be greater than or equal the length of the culvert or the bridge divided by 20 as shown in the figure below.



6.5 Box culverts shall not be used in areas where moving sand can bury the pipeline unless the pipeline is coated in accordance with SAES-H-002.

6.6 A reinforced concrete slab or concrete encasement shall be installed when the minimum required depth of cover cannot be provided. The concrete slab Standard Drawing AB-036255 shall be used as a guideline. The concrete encasement Standard Drawing AB-036660 shall be used as guideline.

6.7 When the stresses in the pipeline or the casing exceeds the allowable stresses per Sections 7 and 12, the following may be considered to reduce or eliminate the stresses:

- Installing concrete slab.
- Increasing the depth of cover.
- Increasing the pipeline wall thickness.
- Reinforcing the pipeline with sleeve.

6.8 The casing or the portion of the carrier pipe under the road with larger wall thickness shall extend at least one meter beyond the edge of the road or railroad shoulders.

6.9 The crossing for all roads shall be made as nearly perpendicular to the road or railroad axis and as straight as practicable. The crossing angle shall not be less than 45 degrees. If this requirement can not be met, the routing of the pipeline shall be reviewed and approved by the Chairman of Piping Standards Committee and the operating department.

6.10 For all roads travelled by motorized vehicles having four wheels or more, the pipeline shall be protected against vehicle collision by means of suitable traffic

barriers, walls, earth berms, or stabilized berm over the pipe beyond the edge of the road (measured at a 90-degree angle to the road) as stipulated below:

6.10.1 Saudi Government maintained railroads and paved roads, pipeline protection shall extend for a distance of at least 30 m from the edge of the road. If a stabilized berm is used for protection, the berm shall provide at least 1 m cover over the top of the pipe.

6.10.2 For Saudi Aramco maintained paved roads or unpaved rig roads and camel crossings, pipeline protection shall extend for a distance of at least 15 m from the edge of the road. If a stabilized berm is used for protection, the berm shall provide at least 1 m cover over the top of the pipe.

7 Design Calculations for Steel Pipe

7.1 The pipeline shall meet the design requirement per SAES-L-410. The stresses affecting the uncased pipeline must be accounted for comprehensively, including both circumferential and longitudinal stresses.

The design procedure for steel pipe shall be according to the latest edition of API RP 1102 or SAER-6078, Analysis and Design of Buried Pipeline (ADBP) developed by Saudi Aramco.

Crossi software developed by Saudi Aramco uses a very conservative approach. It can be used subject to the approval of the Chairman of the Piping Standard Committee.

Commentary Note:

If the Crossi stresses are within the acceptable limits, then there is no need to conduct further analysis using other methodologies.

7.2 Pipelines Designed According to API RP 1102

7.2.1 The soil density should be taken as 120 lb/ft^3 for the earth load calculations. Higher value shall be used based on the field data.

7.2.2 The design wheel load should be either the maximum wheel load from a truck's single axle, or the maximum wheel load from a truck's tandem axle set.

7.2.3 The governing effective stresses shall not exceed 90% of the specified minimum yield strength (SMYS) in steel casings and in uncased steel carrier pipes.

Commentary Note:

For determining the pipe wall thickness due to internal pressure, the design factor "F" shall be based on the appropriate location class.

7.3 Pipelines Designed according to ADBP (SAER-6078)

7.3.1 ADBP shall be used only for highway crossings.

7.3.2 Traffic load classification AR-2, AR-10, AR-20 and AR-40 are based on the tire load and should be used in the stress calculation as required. Unlisted traffic load classifications can be evaluated based on the tires load. Refer to Appendix B.

7.3.3 The effective stresses shall not exceed 90% of the pipe SMYS.

7.3.4 The modulus of soil reaction should be 150 psi. Higher value shall be used based on the field data.

7.3.5 Winkler spring coefficient (ko) depends on pipe diameter and can be calculated for sandy soil from the following expression:

$$k_o = \left(\frac{D+1}{2D}\right)^2 D\,k_s$$

where D is pipe diameter in feet and ks (lb/in³) is the modulus of subgrade reaction. Terzaghi suggested the range of ks for loose sand from 25 to 70 lb/in³.

8 Casing Design

8.1 Casings shall be designed to withstand the superimposed loads.

8.2 If a steel split sleeve is used, it shall be continuously welded in accordance with SAES-W-012 using longitudinal butt welds or side straps with fillet welds. The split sleeve for restarined pipeline Standard Drawing AB-036880 shall be used as guideline.

8.3 The inside diameter of the casing shall be large enough to facilitate installation of the carrier pipe and to prevent the transmission of external loads to the carrier pipe. The casing pipe shall be at least two nominal pipe sizes larger than the carrier pipe.

8.4 For utility lines, except for steam lines, more than one carrier pipe may be placed inside a common casing within a plant area subject to review and

approval by the Chairman of Piping Standards Committee in Consulting Services Department.

8.5 The minimum nominal wall thickness of steel casing shall be in accordance with Table 2.

Table 2 – Steel Casing Wall Thickness

	Minimum Nominal Wall Thickness	
Nominal Pipe Diameter (inches)	**Railroads (mm)**	**Highways (mm)**
14 and Under	4.77	3.40
16	5.56	3.40
18	6.35	3.40
20	7.14	3.40
22	7.14	4.17
24	7.92	4.17
26	8.74	4.17
28	9.53	4.17
30	10.31	4.17
32	11.13	4.17
34	11.91	4.17
36	11.91	4.17
38	12.70	4.78
40	13.49	4.78
42	14.27	4.78
44	15.09	4.78
46	15.09	5.56
48	15.88	5.56
50	16.66	6.35
52	17.48	6.35
54	18.26	6.35
56	19.05	6.35
60	19.84	6.35

8.6 For fully restrained steel pipelines in hydrocarbon service, if the pipeline operates at a hoop stress greater than 50% of SMYS or if groundwater can be within 450 mm below the bottom of the casing, the ends of the casing shall be water-tight seal welded with split reducers using longitudinal butt welds. The split reducers shall be butt welded to the casing at the large ends and fillet

welded to the carrier pipe at the small ends. Welding shall be performed in accordance with SAES-W-012.

8.7 The ends of casings which are not designed per paragraph 8.6 above shall be sealed with flexible non-metallic material to keep out soil and water. The casing end seals shall accommodate the maximum axial movement of the carrier pipe without being torn or cut. The sealing material shall be resistant to ultraviolet light.

8.8 The annulus between the casing and carrier pipe shall be clean (no debris) and dry when the seals are installed.

8.9 Except for casing designed per paragraph 8.6 above, steel casing shall be electrically isolated from the metallic carrier pipe. Where electrical isolation is required, the carrier pipe shall be supported within the casing by means of coated supports or insulators installed at regular intervals. When insulators are used, double insulators are required at each end with the first insulator within one foot of the casing end. The Standard Drawing AB-036660 shall be used as guideline.

8.10 Venting of sealed casings is not mandatory; however, if vents are installed they should be protected from the weather to prevent water from entering the casing.

9 Corrosion Protection

9.1 The external surface of steel casing and casing to be thrust bored shall be coated in accordance with SAES-H-002.

9.2 Steel carrier pipe inside casing with flexible end seals shall have a holiday free fusion-bonded-epoxy coating and heat-shrink sleeves at girth welds. The coating shall be holiday tested just before insertion into the casing.

9.3 Steel pipe encased in concrete shall have additional coating or heat-shrink sleeves, or welded sleeves extending beyond the concrete to approximately 300 mm inside the concrete.

9.4 Uncased carrier pipe and/or steel pipe to be installed by thrust boring shall be coated in accordance with SAES-H-002.

9.5 Cathodic protection is required in accordance with SAES-X-400. Casing welded to the carrier pipe shall be considered part of the pipeline. Casing electrically isolated from the carrier pipe shall have a separate dedicated Cathodic Protection system.

10 Installation

10.1 The design shall include construction specifications covering method of installation, use of a temporary bypass per GI-1021.000, protection of the pipeline, and protection of the road or the railroad.

10.2 Backfill shall be free of material that may damage coatings of steel casing or carrier pipe in accordance with SAES-L-450 and SAES-A-114.

10.3 For railroad and highway crossings, all longitudinal welds should be at the 45, 135, 225, or 315 degree position with the top of the pipe considered the zero degree position.

10.4 For ncased pipe installed by thrust boring, the pipe shall be coated in accordance with paragraph 9.4, and a 13 mm larger outside diameter lead end shall be used during thrust boring and cut off afterwards.

10.5 The road pavement and sub-base shall be restored according to SAES-Q-001 and SAES-Q-006. The surface shall be compacted and finished flush with the adjoining pavement.

10.6 An intermediate plate anchor shall be designed in accordance with SAES-L-440 for uncased crossings of above ground unrestrained steel pipelines if the buried length is not long enough to provide the friction force required to anchor the pipeline.

10.7 Elevation of pipelines under crossings shall not be lower than the adjacent length of the pipeline. This is to minimize acceleration of potential internal corrosion.

When this is not feasible, a review and approval from the Chairman of Piping Standards Committee in the Consulting Services Department is required.
Oil flowlines, test lines and water lines 24" NPS and smaller are excluded from this requirement.

10.8 Trenchless pipeline construction shall be in accordace with SAES-L-470.

11 Testing and Inspection

11.1 The carrier pipe shall be visually inspected prior to installation.

11.2 Externally coated carrier pipe shall be holiday tested prior to installation.

11.3 Welds in carrier pipe shall be inspected by non-destructive test methods in accordance with SAES-W-011 or SAES-W-012 as applicable.

11.4 After installation of a cased crossing with non-metallic casing seals, a test shall show that the steel carrier pipe is electrically isolated from the steel casing pipe.

11.5 The carrier pipe shall be hydrostatically tested at the same pressure as the overall pipeline per SAES-L-150.

11.6 The welds of casings that do not have flexible seal at the ends shall be tested for leaks with air at 20 to 35 kPa (3 to 5 psi) and soap suds or other liquid application technique. (Refer to ASTM E515).

12 Non-Metallic Piping Road Crossings

12.1 Steel casing according to this standard shall be used for non-metallic piping under highway and rail roads. Direct burial crossings are allowed only for piping system in water services with design pressure less than or equal 150 psig.

12.2 The minimum depth of cover to direct burial shall be 1.8 meters from the top of the line to the bottom surface of the asphalt. The minimum depth of the cover at the road shoulders is 1.2 meters.

12.3 RTR pipe design under road crossing shall be according to AWWA M45.

12.3.1 The live load is calculated for a single-axle truck traveling perpendicular to the pipe on an unpaved surface or a road with flexible pavement.

$$W_L = 1.2 \times \frac{F_{wheel} \times I_f}{L_1 \times L_2}$$

$$I_f = 1 + 0.33 \times \frac{96 - H}{96} \geq 1.0$$

The load widths L_1 and L_2 are a function of the depth of cover H and the tire footprint length TL and width TW

$$L_1 = TL + 1.15 \times H$$

$$L2 = TW + 1.15 \times H \qquad \text{if } H \leq H_{int}$$

$$L_2 = \frac{TW + 72 + 1.15 \times H}{2} \qquad \text{if } H > H_{int}$$

Where the depth at which load from wheels interacts Hint is

$$H_{int} = \frac{72 - TW}{1.15}$$

Where:

F_{wheel} = force exerted by wheel on the ground in lb.

I_f = impact factor

H = depth of cover, from ground surface to top of pipe in inches.

H_{int} = depth at which load from wheels interacts in inches.

TL = length of tire footprint in inches.

TW = width of tire footprint in inches.

12.3.2 The ovality of the buried pipe under soil and live (surface) loads shall not exceed the manufacturer limit ($\Omega_{mfr)}$, where the ovality is AWWA M45 eq. (5-8)]

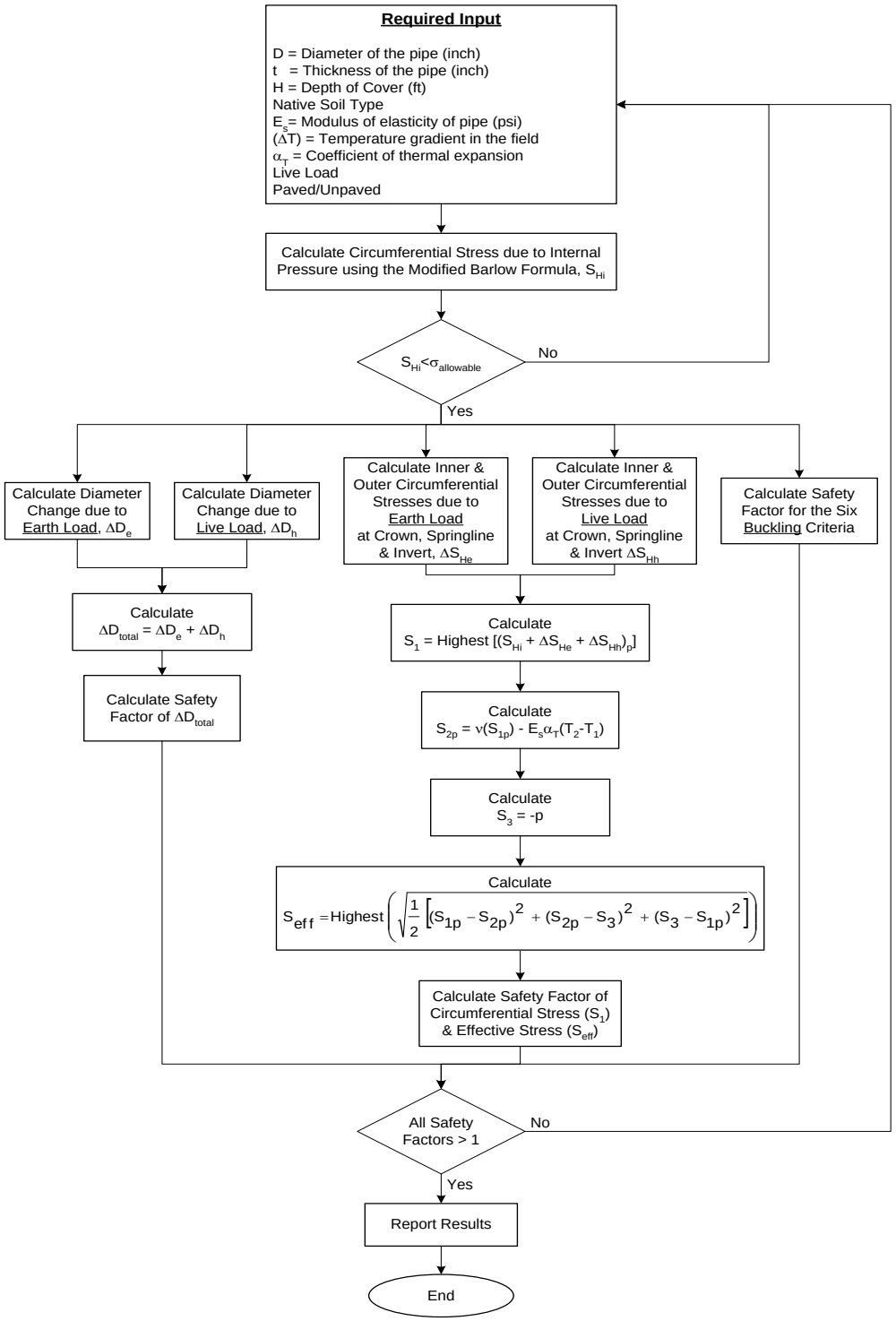
12.3.3 RTR piping not meeting the requirements of paragraph 12.3.1 shall have a steel or concrete encasement. The steel casing design shall be according to Section 8.

12.4 Bedding and backfill over plastic and reinforced thermosetting resin carrier pipe shall be in accordance with SAES-L-610, SAES-L-650 and SAES-S-070 as applicable.

Revision Summary

16 March 2009	Major revision.
6 May 2009	Editorial revision.
10 November 2012	Editorial revision.

Appendix A – Crossing Design Flow Chart Using ADBP



Appendix B – Typical Tire Loads for Trucks

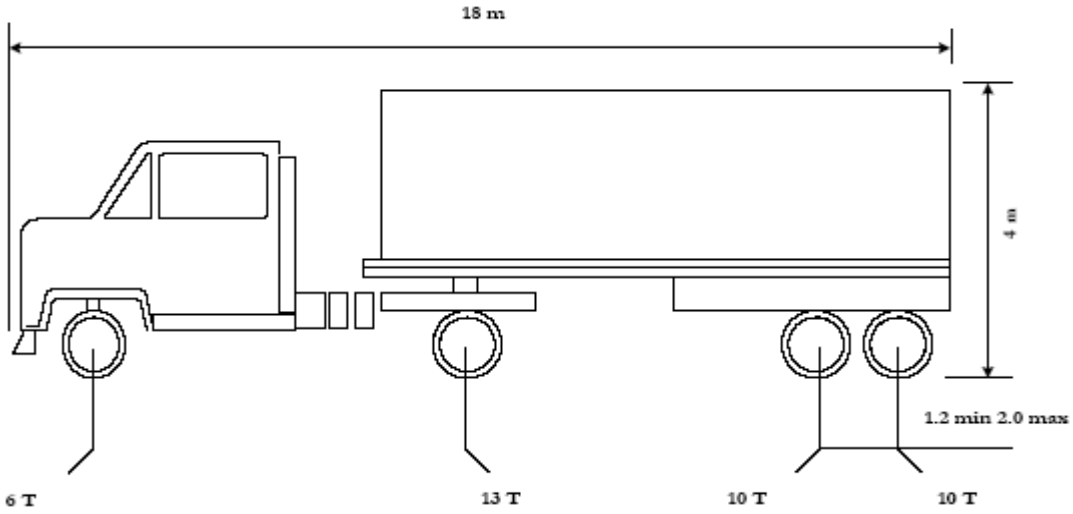


Figure B.1 – Tire Load of 11 kips

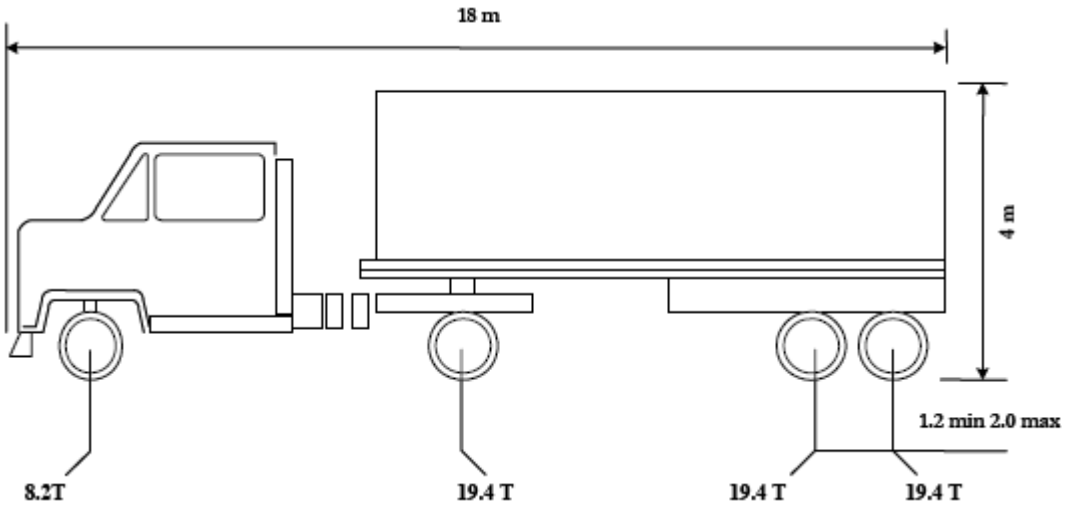


Figure B.2 – Tire Load of 21.5 kips