protective or corrective measures may be used to control detrimental internal corrosion:

1. removal of corrosive agents. If the piping system can effectively launch, pass, and receive cleaning pigs, a cleaning program may be implemented or existing pigging frequencies increased. Careful consideration shall be given when choosing the type of cleaning pig to insure that a thorough cleaning is achieved and to prevent damage to the piping system and, if applicable, to the internal coating system.

2. an effective chemical treatment may be applied in a manner and quantity to protect all affected portions of the piping system.

3. addition of fittings for removal of contaminants from low spots, or positioning of the piping to reduce holdup of contaminants.

4. application of an internal coating.

5. Internal corrosion control measures shall be evaluated by a program that includes

   1. periodically checking any chemical additive system.

   2. evaluation of corrosion coupons and test spools at periodic intervals.

   3. periodically checking corrosion probes to help evaluate control of pipeline internal corrosion.

   4. maintaining a record of the internal condition of the pipe, of leaks and repairs from corrosion, and corrosivity of gas, liquids, or solids. The record should be used as a basis for changes in the cleaning schedule, chemical treatment program, or gas treatment facility.

   5. periodic measurements of piping component remaining wall thickness.

   4. Where examination, observation, or record analysis indicates internal corrosion is taking place to an extent that may be detrimental to public or employee safety, that portion of the system shall be repaired or reconditioned, and steps shall be taken to mitigate the internal corrosion.

**GR-5.3.2 Repair of Corroded Pipe**

If the extent of corrosion has reduced the strength of a facility below that needed for the prescribed allowable operating pressure, that portion shall be repaired, reconditioned, or replaced, or the operating pressure shall be reduced, commensurate with the remaining strength of the corroded pipe. For steel pipelines, the remaining strength of corroded pipe may be determined in accordance with ASME B31G, Manual for Determining the Remaining Strength of Corroded Pipelines, or other accepted method.

**GR-5.4 LEAKAGE SURVEYS**

Each operating company shall provide for periodic leakage surveys of the facility in its operating and maintenance plan. The types of surveys selected shall be effective for determining if potentially hazardous leakage exists. The extent and frequency of the leakage surveys shall be determined by the operating company, considering the operating pressure, hoop stress level, piping age, class location, and whether the transmission line transports hydrogen without an odorant. In no case shall the interval between surveys exceed 12 months.

**GR-5.5 REPAIR PROCEDURES**

The provisions in paras. GR-5.5 through GR-5.10 are applicable to all piping, pipelines, and mains.

(a) If at any time a defect is evident, temporary measures shall be employed immediately to protect the property and the public. If it is not feasible to make permanent repairs at the time of discovery, permanent repairs shall be made as soon as feasible as described herein. The use of a welded patch as a repair method is prohibited. If the facility is not taken out of service, the operating pressure shall be at a level that will provide safety during the repair operations.

(b) Before opening any piping to atmosphere, the system shall be purged so that the concentration of flammable gas is less than the lower flammability limit in air. Before reintroducing flammable gas into a system, reduce the concentration of air in the piping to a level that prevents a combustible mixture.

(c) A full encirclement welded split sleeve with welded ends shall have a design pressure at least equal to that required for the maximum allowable operating pressure of the pipe being repaired. See the requirements for the applicable Part of this Code. If conditions require that the sleeve carry the full longitudinal stresses, the sleeve shall be at least equal to the design strength of the pipe being repaired. Full encirclement sleeves shall not be less than 100 mm (4 in.) long.

(d) If the defect is not a leak, this Code permits the circumferential fillet welds to be omitted in certain cases. If circumferential fillet welds are not made, the longitudinal welds may be butt welds or fillets to a side bar. The circumferential edges, which would have been sealed had the fillet weld been made, should be sealed with a coating material such as enamel or mastic, so that corrosive elements will be kept out of the area under the sleeve. Prior to the installation of a sleeve, the pipe body shall be examined by ultrasonic methods for laminations where sleeve fillet welds will be made.

**GR-5.6 INJURIOUS DENTS AND MECHANICAL DAMAGE**

(a) Plain dents are injurious if they exceed a depth of 6% of the nominal pipe diameter. Plain dents of any depth are acceptable, provided strain levels associated with the deformation do not exceed 2% strain. Strain levels may be calculated in accordance with Nonmandatory Appendix C or other engineering methodology. In
NONMANDATORY APPENDIX D
ESTIMATING STRAIN IN DENTS

D-1 STRAIN

Strain in dents may be estimated using data from deformation in-line inspection (ILI) tools or from direct measurement of the deformation contour. Direct measurement techniques may consist of any method capable of describing the depth and shape terms needed to estimate strain. The strain estimating techniques may differ depending on the type of data available. Interpolation or other mathematical techniques may be used to develop surface contour information from ILI or direct measurement data. Although a method for estimating strain is described herein, it is not intended to preclude the use of other strain estimating techniques. See also Fig. D-1.

D-2 ESTIMATING STRAIN

$R_0$ is the initial pipe surface radius, equal to one-half the nominal pipe O.D. Determine the indented O.D. surface radius of curvature, $R_1$, in a transverse plane through the dent. The dent may only partially flatten the pipe such that the curvature of the pipe surface in the transverse plane is in the same direction as the original surface curvature, in which case $R_1$ is a positive quantity. If the dent is reentrant, meaning the curvature of the pipe surface in the transverse plane is actually reversed, $R_1$ is a negative quantity. Determine the radius of curvature, $R_2$, in a longitudinal plane through the dent. The term $R_2$, as used herein will generally always be a negative quantity. Other dimensional terms are the wall thickness, $t$, the dent depth, $d$, and the dent length, $L$.

(a) Calculate the bending strain in the circumferential direction as

$$
\epsilon_1 = \frac{1}{2} \left( \frac{t}{R_0} - \frac{t}{R_1} \right)
$$

(b) Calculate the bending strain in the longitudinal direction as

$$
\epsilon_2 = \frac{1}{2} \left( \frac{t}{R_2} \right)
$$

(c) Calculate the extensional strain in the longitudinal direction as

$$
\epsilon_3 = \frac{1}{2} \left( \frac{t}{L} \right)
$$

(d) Calculate the strain on the inside pipe surface as

$$
\epsilon_i = \left[ \epsilon_1 - \epsilon_2 \right] + \left( \epsilon_2 + \epsilon_3 \right)^{1/2}
$$

and the strain on the outside pipe surface as

$$
\epsilon_o = \left[ \epsilon_1 + \epsilon_2 \right] + \left( -\epsilon_2 + \epsilon_3 \right)^{1/2}
$$
NONMANDATORY APPENDIX C
RECOMMENDED PRACTICES FOR PROOF TESTING OF PIPELINES IN PLACE

C-1 INTRODUCTION

The purpose of this Nonmandatory Appendix is to cite some of the important steps that should be taken in the proof testing of in-place pipelines. It is intended to provide basic guidelines only. Paragraph C-2.8 of this recommended practice is used for the determination of the pressure at which the pipe actual yield strength is achieved in testing. All pressure tests shall be conducted with due regard for the safety of people and property. When test pressure is above 400 psig, appropriate precautions shall be taken to keep people not engaged in the testing operations out of the testing area while conducting the test.

C-2 HYDROSTATIC TESTING

C-2.1 Selection of Test Sections and Test Sites

The pipeline may need to be divided into sections for testing to isolate areas with different test pressure requirements or to obtain maximum and minimum test pressures due to hydrostatic head differential. The elevation at the test site, the high point and low point of the isolated area, must be known to maintain the specified pressure at the maximum and minimum elevations.

C-2.2 Water Source and Water Disposal

A water source, as well as location(s) for water disposal, should be selected well in advance of the testing. Federal, state, and local regulations should be checked to ensure compliance with respect to usage and/or disposal of the water. In disposing of the water after testing, care should be taken to prevent damage to crops and excessive erosion or contamination of streams, rivers, or other water bodies, including groundwater.

C-2.3 Ambient Conditions

Hydrostatic testing in low-temperature conditions may require the following:

(a) heating of the test medium.

(b) the addition of freeze-point depressants. Caution should be exercised in the handling of freeze-point depressants during tests. Disposal of freeze-point depressants must be carefully planned and executed.

C-2.4 Filling

Filling is normally done with a high-volume centrifugal pump or pumps. Filling should be continuous and be done behind one or more squeegees or spheres, to minimize the amount of air in the line. The progress of filling should be monitored by metering the water pump into the pipeline and calculating the volume of line filled. If necessary, a period of temperature stabilization between the ground and fill water should be provided.

C-2.5 Pressure Pump

Normally, a positive displacement reciprocating pump is used for pressurizing the pipeline during testing. The flow capacity of the pump should be adequate to provide a reasonable pressurizing rate. The pressure rating of the pump must be higher than the anticipated maximum test pressure.

C-2.6 Test Heads, Piping, and Valves

The design pressure of the test heads and piping, and the rated pressure of hoses and valves in the test manifold, shall be no less than the anticipated test pressure. All equipment should be inspected prior to the test to determine that it is in satisfactory condition.

C-2.7 Pressurization

The following is a sequence for pressurization:

(a) Raise the pressure in the section to not more than 80% of anticipated test pressure, and hold for a time period to determine that no major leaks exist.

(b) During this time period, monitor the pressure and check the test section for leakage. Repair any major leaks that are found.

(c) After the hold time period, pressurize at a uniform rate to the test pressure. Monitor for deviation from a straight line by use of pressure-volume plots (logs or automatic plotter).

(d) When the test pressure is reached and stabilized from pressuring operations, a hold period may commence. During this period, test medium may be added as required to maintain the minimum test pressure.

C-2.8 Determination of Pressure Required to Produce Yielding

Yield strength determined in this manner is actual yield strength rather than specified minimum yield.