US Army Corps of Engineers

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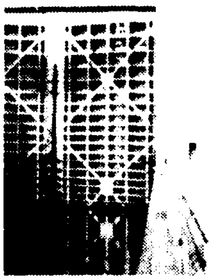

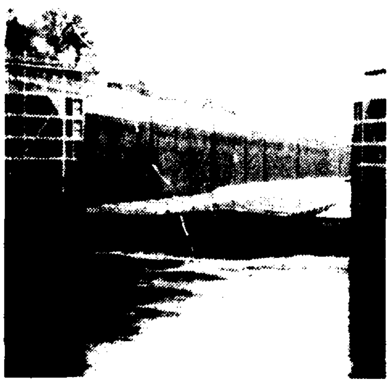

REMR RESEARCH PROGRAM

(2)

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-OM-08

REMR MANAGEMENT SYSTEMS—NAVIGATION STRUCTURES

MANAGEMENT SYSTEM FOR MITER LOCK GATES

by

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US ARMY CORPS OF ENGINEERS CONSTRUCTION ENGINEERING RESEARCH LABORATORY CERL

December 1990
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GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

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Recently, the mission of the US Army Corps of Engineers has been shifting from constructing new facilities to maintaining the large inventory of existing facilities. The miter lock gates within Corps' civilian projects are the focus of this research.

The objectives of this work were (1) to develop an inspection and rating system that uniformly and consistently describes the current condition of miter lock gate structures, and (2) to develop guidelines for the maintenance and repair of these structures.

After inspection data are gathered, they are filed on a computer disk through a microcomputer program. The program will then compute the structural and functional condition indexes for miter lock gates. The program user can create a plot of condition index versus time and formulate a number of maintenance and repair solutions from a set of alternatives. Consequences of the various solutions are quantified by reevaluating the condition index. When the initial costs, expected life, downtime costs, interest rates, and inflation rates are known, a preliminary life cycle cost analysis can be performed. With this information, an experienced engineer can make a preliminary maintenance and repair plan for the structure.

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PREFACE

This study was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Unit 32280, "Development of Uniform Evaluation for Procedures/Condition Index for Deteriorated Structures and Equipment," for which Dr. Anthony M. Kao is Principal Investigator. This work unit is part of the Operations Management problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program sponsored by HQUSACE. Mr. James E. Crews (CECW-OM) is the REMR Technical Monitor for this work.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C) is the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Mr Crews and Dr. Tony C. Liu (CECW-ED) serve as the REMR Overview Committee; Mr. William F. McCleese (CECW-OM), US Army Engineer Waterways Experiment Station, is the REMR Program Manager. Dr. Kao is also the Problem Area Leader for the Operations Management problem area.

The study was performed by the College of Engineering, Iowa State University, under contract to the US Army Construction Engineering Research Laboratory (USACERL). Principal Investigators for Iowa State University were Professors Lowell Greimann and James Stecker. Kevin Rens was the research assistant.

The study was conducted under the general supervision of Dr. Robert Quattrone, Chief of Engineering and Materials Division (EM) of USACERL, and under the direct supervision of Dr. Kao, EM, who was the Contracting Officer's Representative. The USACERL Technical Editor was Gloria Wienke, Information Management Office.

COL Everett R. Thomas is Commander and Director of USACERL and Dr. L.R. Shaffer is Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be coverted to SI (metric) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
inches	0.0254	metres

MAINTENANCE AND REPAIR OF MITER LOCK GATES

PART I: INTRODUCTION

Background

1. The US Army Corps of Engineers has acquired and completed a large inventory of civilian projects over the past 100 years. For much of this time, the Corps concentrated on designing and constructing new facilities, such as locks and dams on navigable inland waterways and coastal systems, and on power generation. Recently, the mission of the Corps has been shifting from constructing new facilities to maintaining existing facilities. Two factors that have prompted this shift are: (1) many existing structures are nearing the end of their design life, and (2) fewer opportunities for expansion of Corps projects are available. The Corps has addressed its changing role by instituting a Repair, Evaluation, Maintenance, and Rehabilitation (REMR) program. As this name implies, the general topic of maintenance encompasses several stages. To some extent, each stage requires the development of a new technology and methodology.

2. As a part of this program, the project team at Iowa State University (ISU) has undertaken a research effort focusing on the evaluation and repair of the miter lock gate structures within the Corps' civilian projects. To ensure a continuous working life for the structures, it is necessary to maintain an adequate inspection program. Such a program must be capable of detecting problems at an early stage. This allows engineers time to analyze inspection information and suggest remedial action if required. An ongoing rigorous inspection program gives confidence because serious defects should be detected before they become catastrophic (Bayliss, Short, and Bax 1988).

3. Miter lock gates are an important operating component of a lock and dam facility. If these structures fail to function or function improperly, operation of the lock is severely affected. In many situations, only one lock is available at a dam site. If this lock does not function, navigation along the entire river is delayed, resulting in large user costs. Gates are a critical item; they are probably the most frequent cause of lock shutdown for repair and maintenance.

Objectives

4. The objectives of this work are to:

   a. Develop a uniform procedure to describe the current condition of miter lock gate structures (Greimann, Stecker, and Rens 1989), and

b. Develop guidelines for the maintenance and repair of these structures.

Mode of Technology Transfer

5. It is recommended that the inspection procedures developed in this study for miter lock gates be incorporated into Engineer Regulation (ER) 1110-2-100, "Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures." Software will be available from US Army Engineer Waterways Experiment Station's Engineering Computer Program Library (ECPL). Address requests to: Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: CEWES-IM-DS, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199 or call (601) 634-2581. All other inquiries should be directed to Commander and Director, US Army Construction Engineering Research Laboratory, PO Box 4005, Champaign, IL 61824-4005, telephone (217) 373-7011.

Overview

6. The concepts and ideas presented here for the maintenance management of miter lock gates rely heavily on work in a similar project for steel sheet pile structures (Greimann and Stecker, 1988). During that earlier work, basic ideas such as structural and functional condition indexes, safety and serviceability, quantification of distresses by field measurements, limiting values of distresses, repair and maintenance alternatives, and others began to evolve. As these concepts were applied to miter lock gates, several enhancements became apparent and some new ideas appeared.

7. During the course of this project, the project team at ISU held many meetings with Corps personnel and conducted site visits and field investigations at many lock and dam facilities. At these meetings and site visits, several basic considerations for miter lock gates were identified. Corps experts conveyed their opinions on the critical components of miter lock gate operation and repair. They suggested methods of quantifying these components and relating them to the overall condition of the miter gates. The project team took the experts' comments, formulated them into an inspection procedure and a tentative set of rating rules, and conducted field tests of the inspection form and rating rules at five gate sets. At each test site, experts suggested additional improvements to the rules and inspection process. Insofar as possible, except for cases of conflicting expert opinion, the suggestions have been incorporated into this work.

Field inspection

8. The maintenance and repair procedure is illustrated schematically in Figure 1. The entire process is based on a thorough field inspection of the

miter lock gate structure. During this inspection, current physical attributes of the systems are obtained. Data, such as the location of the gate, inspection history, historical water level, and maintenance history, are recorded on the first two pages of the inspection form. Other inspection form pages are used to describe some of the structural details, such as girder cross sections, skin plate, and intercostal size. The information on these pages is used as the basis for a structural evaluation of the gate. Additional pages provide space for entering several field measurements such as anchorage movements, elevation changes, downstream movement, cracks, dents, and corrosion. These measurements are used directly to rate the condition of the gate.

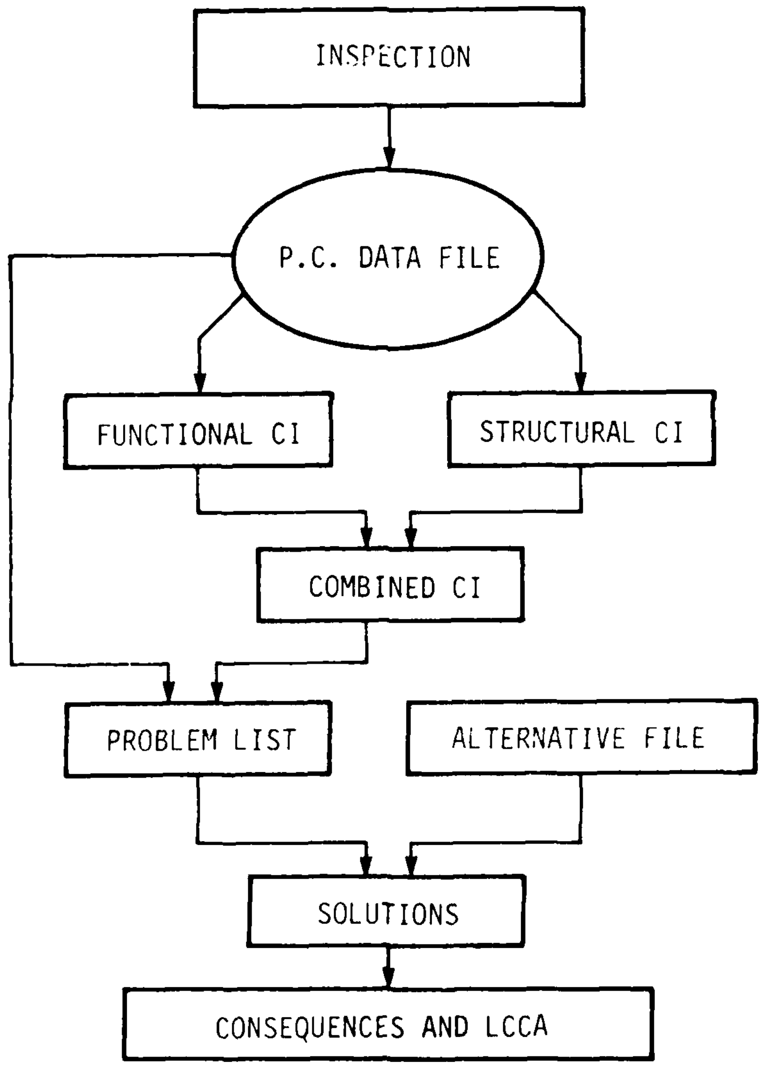


Figure 1. Maintenance and repair analysis of miter lock gate

9. The information collected on the inspection form is entered into a data file through a program called MITER on a microcomputer. The program permits editing of the file and handles the data for all of the succeeding steps.

Condition index

10. The rating process is the next step. The inspection data is used in MITER to calculate a condition index (CI) for the structure. CI is a numerical measure of the current state of a structure. It is part of the goal of this project to define a CI that uniformly and consistently describes and ranks the condition of miter lock gate structures. The CI is primarily a planning tool, with the index values indicating the general condition level of the structure. The index is meant to focus management attention on those structures most likely to warrant immediate repair or further evaluation. In addition, the CI values can be used to monitor change in general condition over time and can serve as an approximate comparison of the condition of different structures.

11. A common definition of condition index has evolved; The REMR Condition Index is a numbered scale, from a low of 0 to a high of 100, indicating the relative need to perform REMR work because of deterioration of the functional and structural characteristics of the structure. The condition index scale in Table 1 has been adopted. For management purposes, the condition index scale is calibrated to group structures into three basic categories or zones, as listed in Table 2.

12. Two general structural criteria for evaluating the CI are available: safety and serviceability. Safety relates to the performance of a structure beyond normal service conditions, for example, under abnormal conditions such as excessive load. Serviceability relates to the performance of a structure under normal service conditions, for example, excessive leakage. Two condition indexes were formulated to describe the structure relative to these criteria. The first, the structural condition index, is based on a structural analysis of the miter lock gate structure. It includes primarily safety aspects. The second, the functional condition index, is based on field measurements of the distresses and the opinion of experts. It includes both safety and serviceability aspects. (Parts III and IV deal with these two condition indexes in more detail.)

13. As the condition index zones in Table 2 indicate, one purpose of the condition index is to draw attention to a particular problem that may require further investigation (e.g., Zone 3). In this regard, the combined condition index or, simply, the CI will be defined as a

Condition Index = Minimum of:

Structural Condition Index
or
Functional Condition Index

Table 1

Condition Index Scale

Value	Condition Description
85-100	Excellent -- No noticeable defects, some aging or wear visible
70-84	Very Good -- Only minor deterioration or defects evident
55-69	Good -- Some deterioration or defects evident, function not impaired
40-54	Fair -- Moderate deterioration, function is still adequate
25-39	Poor -- Serious deterioration in at least some portions of structure, function inadequate
10-24	Very Poor -- Extensive deterioration, barely functional
0-9	Failed -- General failure or failure of a major component, no longer functional

Table 2

Condition Index Zones

Zone	CI Range	Action
1	70-100	Immediate action not required
2	40-69	Economic analysis of repair alternatives recommended to determine appropriate maintenance action
3	0-39	Detailed evaluation required to determine the need for repair, rehabilitation or reconstruction, safety evaluation required

Hence, if the structure has a poor condition index, the engineer is alerted and can trace back to determine whether the cause is a low structural or functional condition index. Indeed, the engineer would presumably trace back through the entire rating process and possibly conduct a more detailed field inspection or structural analysis to establish the basic cause. Experience indicates that major structural and mechanical problems sometimes develop without warning. Therefore, a District should not become complacent about the condition of a gate as a result of a favorable condition index. Experienced engineers should be relied upon to make judgments regarding the significance of the condition index.

Deterioration analysis

14. After the current combined condition index has been calculated, the user has the option to investigate the effect of time on the condition index. The user enters the required deterioration parameters to view a plot of condition index versus time (Part V deals with deterioration analysis in more detail).

Maintenance and repair analysis

15. After an evaluation of the current condition and deterioration rate of the structure, the user has the option to investigate and compare several maintenance and repair possibilities. After the program has displayed a list of problems associated with a structure, the user can select from a list of maintenance and repair alternatives that would provide various levels of remedial action for each of the distresses. Some alternatives may fix only one distress; others may fix several. A set of alternatives is collected to form one maintenance and repair solution.

16. Several different solutions can be formulated, and the program can be used to compare and evaluate each of them. The consequences of each solution are obtained by calculating a new CI that reflects the as-repaired structure. If the user provides cost and lifetime information about each solution, the program will calculate an annualized cost by a life-cycle cost analysis. With this maintenance and repair analysis option within the program, the user can make a preliminary evaluation of a maintenance plan.

17. Realistically, the program has limitations the user should be aware of. The entire process is intended to be a preliminary assessment. The inspection is not sufficiently detailed to isolate the cause of all distresses. For example, anchorage movement is a symptom of several possible causes (embedded anchorage, eye bar connection, or gudgeon pin). Before selecting a maintenance or repair alternative, the user may need to conduct a more thorough investigation. Some alternatives may not correct the cause. Also, the cost analysis is intended to be indicative only and is based on preliminary estimates. Detailed cost estimates and analyses may be required to differentiate between two competing solutions (Part IV deals with maintenance and repair analysis in more detail).

Miter Lock Gate Component Identification

18. To inspect and rate miter lock gate structures, the user must clearly identify the components; definitions for these components are presented in the following paragraphs. Figure 2 illustrates a typical lock and dam facility.

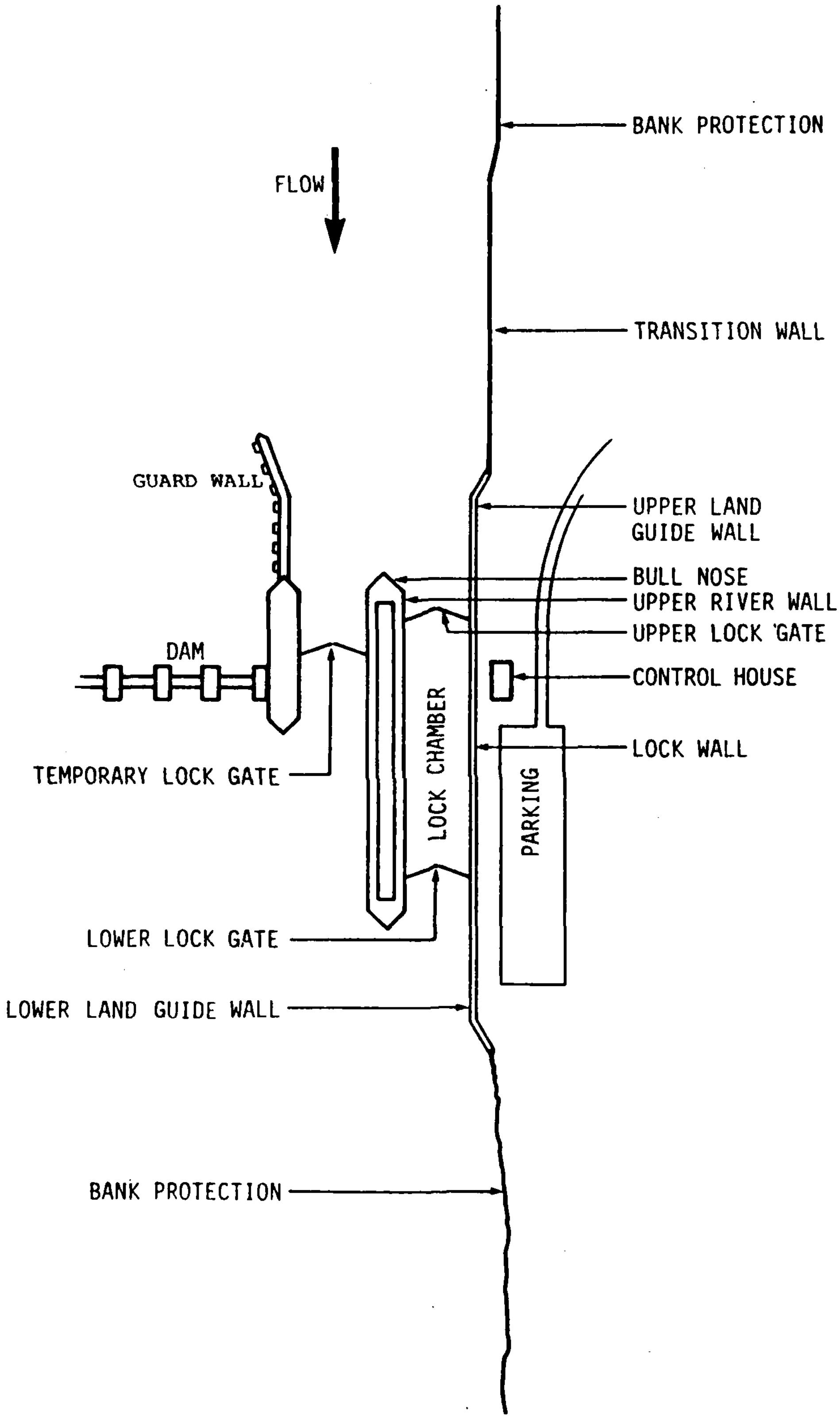


Figure 2. Lock and dam facility

Horizontal girders

19. Horizontal girders are plate steel sections that span horizontally. Their main function is to transfer load to the quoin. In the horizontally framed miter lock gate (Figure 3), the load is transferred from the skin plate through the horizontal girders and back into the lock wall. The bottom horizontal girder on a horizontally framed gate does not transfer load into the sill, but acts as a seal at the bottom of the gate. In a vertically framed gate (Figure 4), there are two horizontal girders that carry the load from the vertical girders. The top girder then transmits the load to the lock wall. The bottom horizontal member transfers the load directly into the sill.

Vertical girders

20. Vertical girders are steel sections that span vertically to transfer load to the horizontal girders. In the vertically framed gate (Figure 4), the load is transferred from the skin plate through the vertical girders to the top and bottom horizontal girder.

Skin plates

21. A skin plate is welded (sometimes riveted) between girders to provide vertical stiffness to the gate leaf. The skin plate dams the water and acts as part of the upstream flange of the girders.

Diaphragms

22. The horizontal girders are connected vertically by several intermediate diaphragms and two end diaphragms, one at the quoin end and one at the miter end of the horizontally framed miter lock gate in Figure 3. The end diaphragms also serve to dam the water in the tapered end section of Figure 5. The vertically framed gate contains no diaphragms.

Intercostals

23. Intercostals are provided between diaphragms on the horizontally framed gate (Figure 3) and between girders on the vertically framed gate (Figure 4). Intercostals serve to stiffen and support the skin plate.

Thrust diaphragms

24. The thrust diaphragm shown in the tapered end section (Figure 5) serves to distribute the horizontal girder reactions from the quoin block into the girder webs.

Quoins

25. The quoin block (located on the gate leaf) and the wall quoin (located on the concrete monolith) serve to transmit bearing forces from the gate to the lock wall. The wall quoin has a concave surface and the quoin block has a convex surface of about the same radius. These two surfaces bear on each other when the gate is in the mitered position. On horizontally framed gates, the quoin block and wall quoin are continuous from the top of the gate to the bottom, as shown in Figure 3. On vertically framed gates

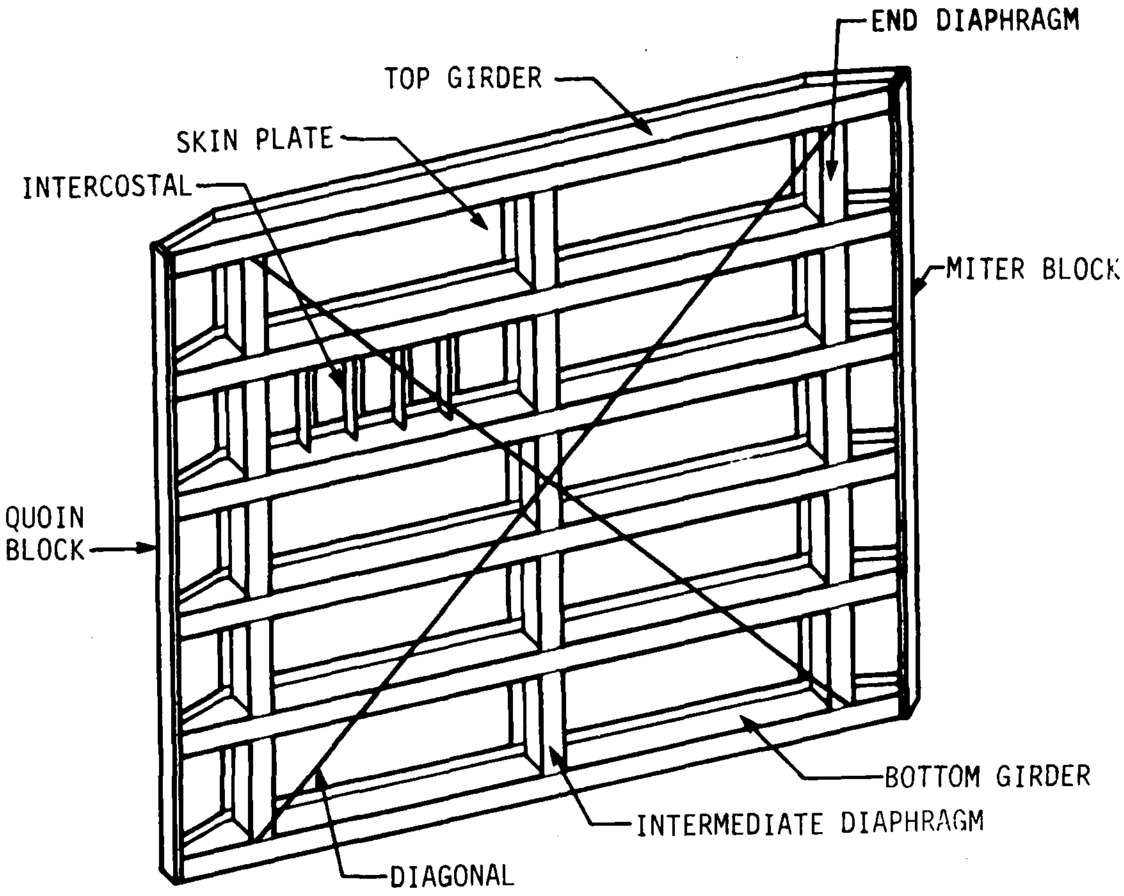


Figure 3. Horizontally framed miter gate

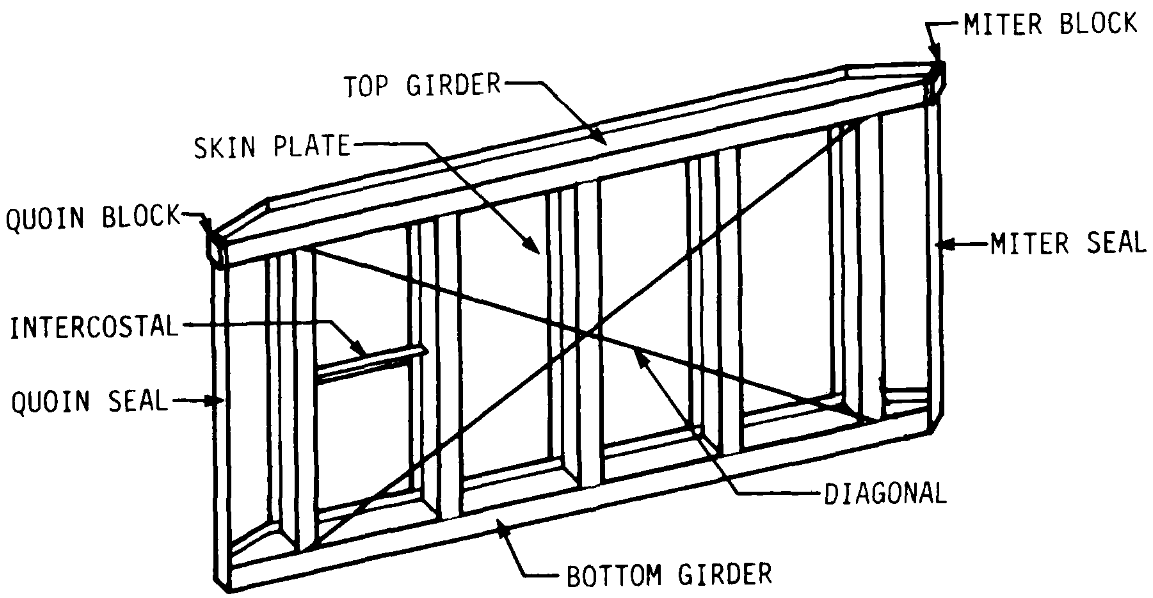


Figure 4. Vertically framed miter gate

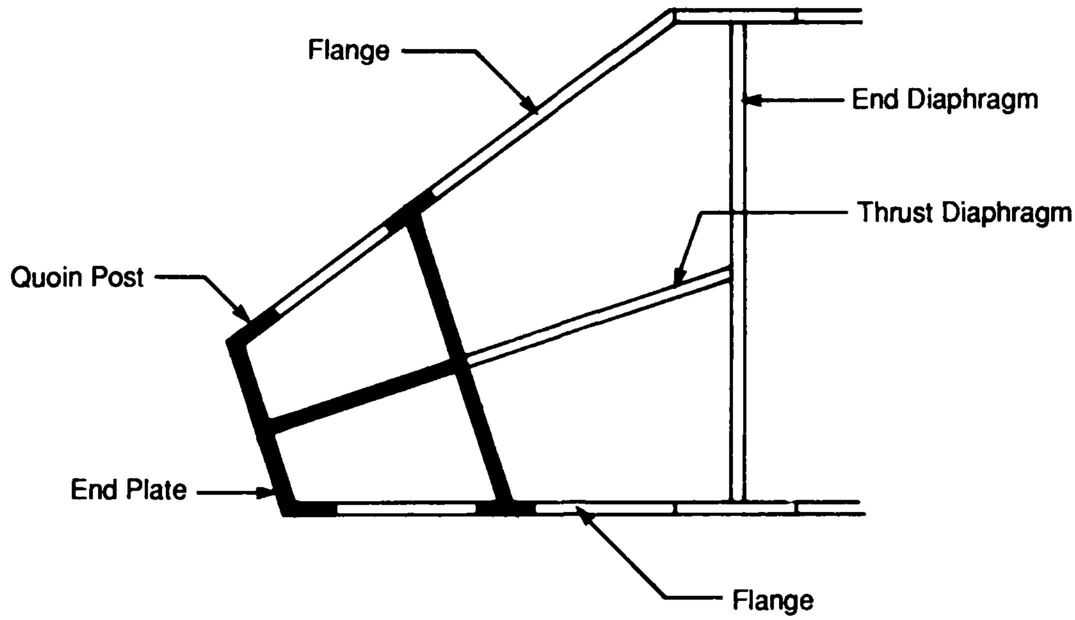


Figure 5. Tapered end and quoin post

(Figure 4), load is transferred into the lock wall at the top girder. The quoin block and wall quoin are present only at this location.

Miter blocks

26. The miter blocks are located at the miter end of the horizontal girders. Miter blocks serve to transmit the axial load of the girders between the two leaves in the mitered position. On horizontally framed gates, miter blocks (like quoin blocks) are continuous along the entire height of the gate. On vertically framed gates, miter blocks (like quoin blocks) are present only at the top and bottom horizontal girder.

Pintles

27. Pintle assemblies used for both horizontally and vertically framed miter lock gates consist of two types: floating and fixed. The floating pintle (Figure 6) fits into a cast steel shoe that is not fastened to the pintle base, allowing the lower corner of the gate leaf to move outward if debris is lodged in the quoin. The fixed pintle fits into a cast steel shoe that is bolted to the pintle base. Keyed pintles, which permit sliding in only one direction, are also used.

Diagonals

28. Strut arms that open and close the gates apply a concentrated force at the top of the gate. This force and the dead weight of the gate are

eccentric with respect to the center of gate stiffness, and they cause the leaf to twist out of plumb. On most horizontally framed gates, the skin is located on the upstream side of the leaf. Adjustable diagonals on the downstream side are pretensioned to keep the gate plumb. For some vertically framed gates, the skin plate is located at the center of the gate, and diagonals are used on both sides of the gate. Some gates have skin on both the upstream and downstream face and do not have diagonals.

Embedded anchorages

29. Embedded anchorages serve to distribute the top reaction of the leaf into the concrete wall (Figure 7).

Anchorage Links

30. The parallel and perpendicular anchorage links are made up of pinned ends connecting the gudgeon pin to the embedded anchorage. Most anchorage links have an adjustable length, typically either a threaded section or wedges. An alternate parallel anchorage arm with a double linkage pin is

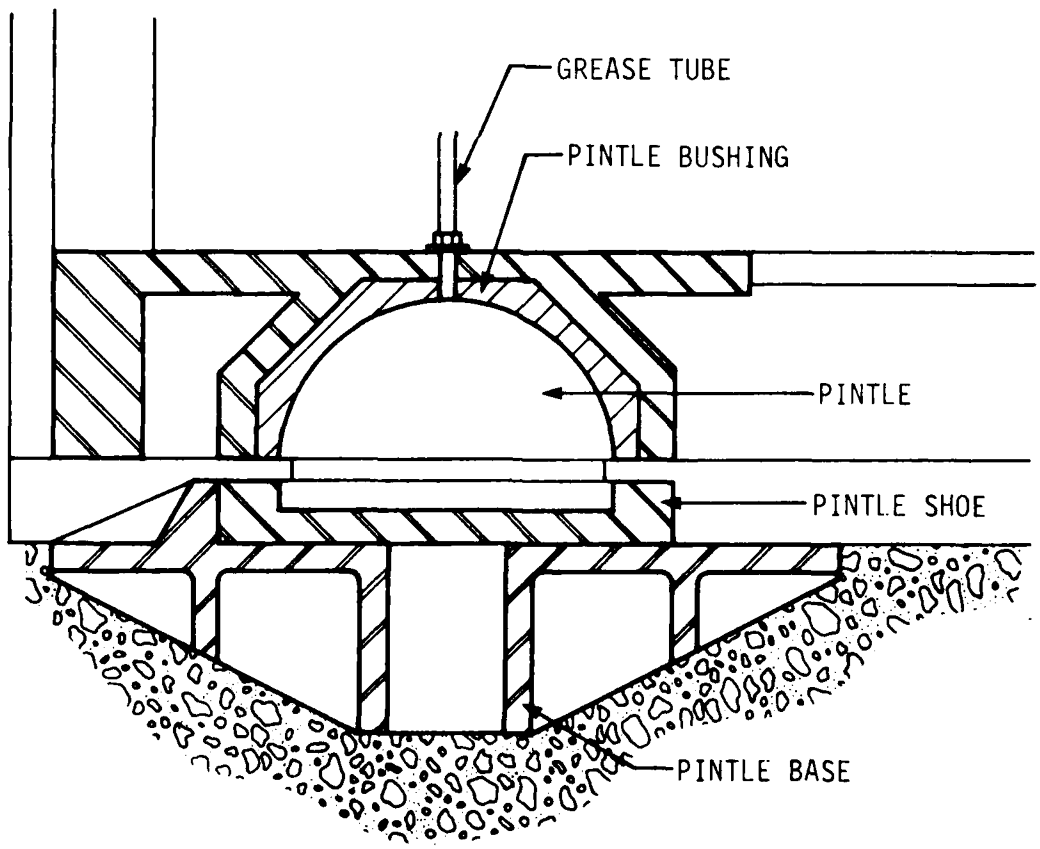
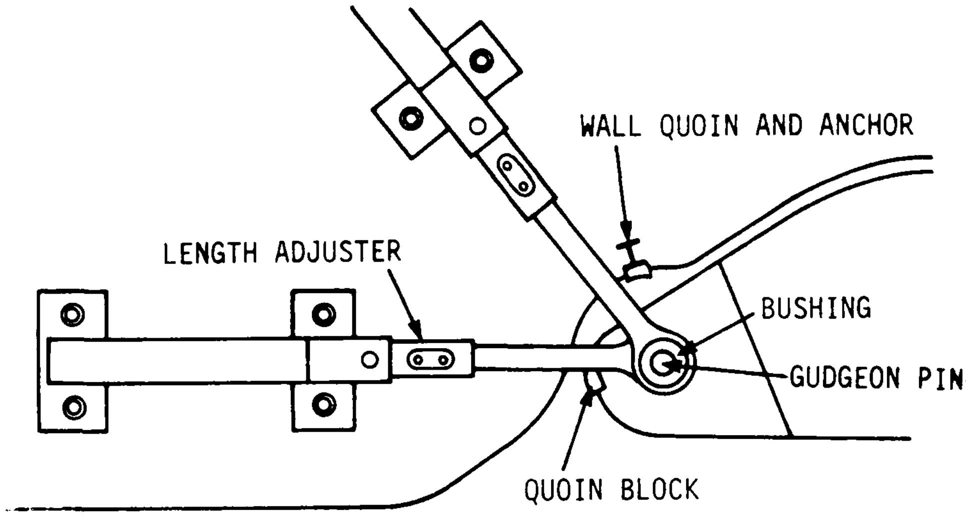


Figure 6. Floating pintle assembly

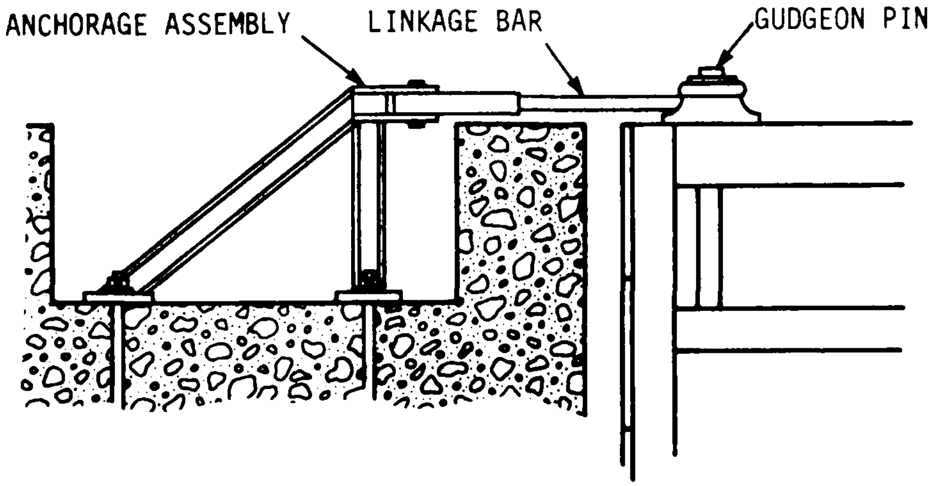
shown in Figure 8. This assembly is made up of two anchor links connected by a linkage pin.

Gudgeon pin and bushing

31. Gudgeon pins are large-diameter pins of forged alloy steel. The gudgeon pin fits into a bronze bushing (Figure 7). This assembly serves as the only connection between the top of the gate and anchorage links.



a. PLAN VIEW



b. SECTION VIEW

Figure 7. Upper anchorage assembly

Seals

32. Rubber seals are used on the bottom of horizontally framed gates. Various types of seals are used, but the most common is the round rubber seal, which is used in regions having a wide range of temperature, and the "J" seal. Seals are used at the quoin and miter on vertically framed gates and at the sill on horizontally framed gates.

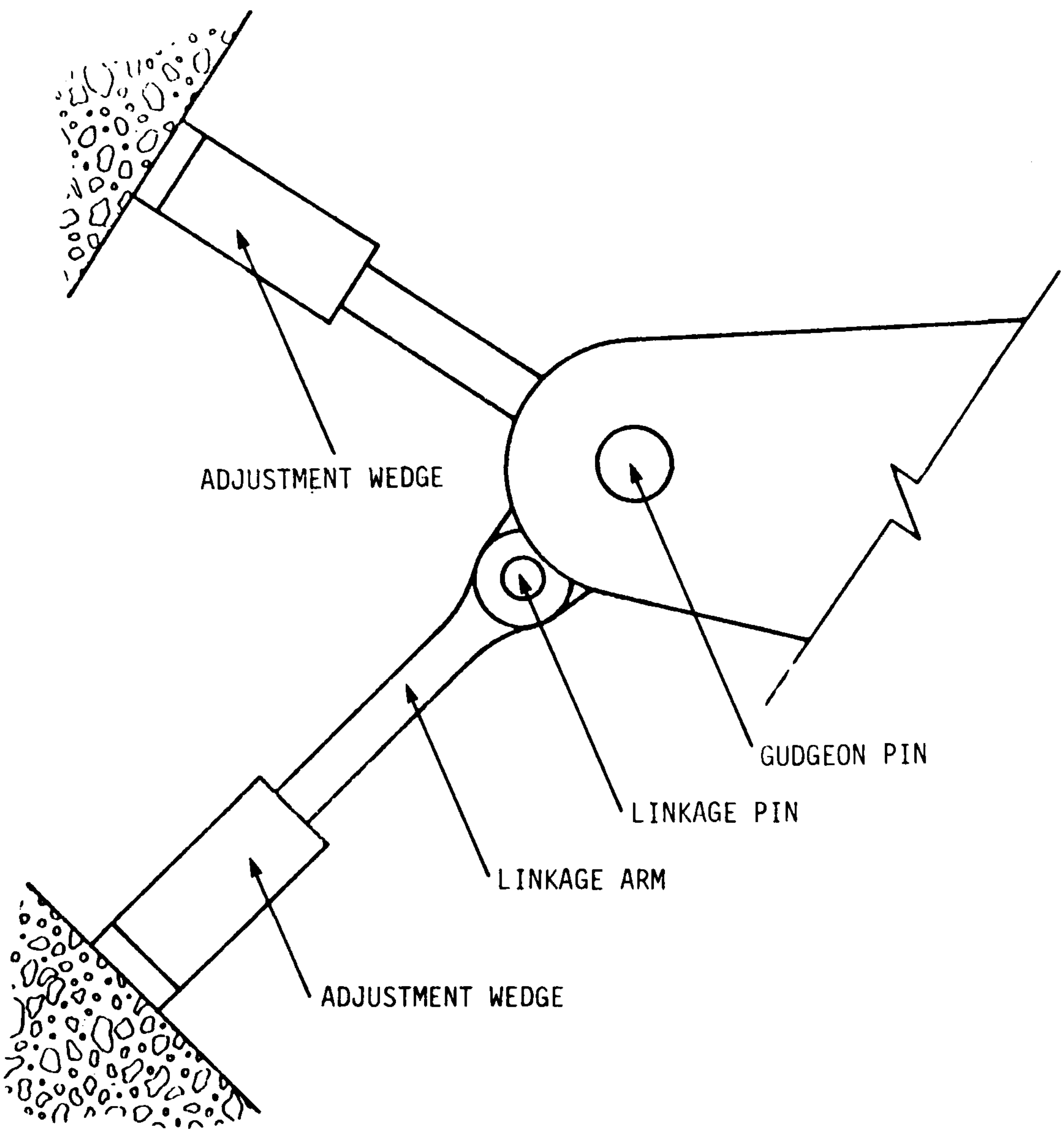


Figure 8. Double linkage pin assembly (components)

PART II: FIELD INSPECTION

33. Two basic ideas behind the inspection procedure are simplicity and adaptability. As meetings and field tests with Corps personnel progressed, it became increasingly clear that any miter lock gate inspection program must be simple to learn and adaptable to different heights of gates. Current inspection procedures varied significantly among the various districts. For high lift locks, inspection procedures tended to be more extensive with less tolerance for misalignments and imperfections. For low lift locks, inspection procedures were not as rigid, and more deviations from the perfect case were tolerated.

34. With these restrictions, the field inspection had to be based on easily obtainable data. In this case, easily obtainable data were taken to be those obtainable from on top of the gate or the lock wall or from a boat in the lock chamber. The normal inspection would involve no underwater diving. No ultrasonic or other "sophisticated" devices could be used. All data would be measured by subjective observation (poor, average, good, excellent, etc.), a tape measure, a level, a ruler, dial gages, a camera, and the like. As a goal, the data would be recorded by technicians having no specific engineering training or experience in the design or construction of miter lock gate structures. Data would be collected from the gate with the lock in an operating mode, that is, not unwatered. Minimal disturbance to lock traffic was a requirement. Of course, if the inspection can be conducted in conjunction with a dewatering or divers, the additional information would be useful. Although inspection by diving teams would help to validate the visual inspection, many Corps personnel stated that diving inspection was not warranted. For the time being, the authors have decided to go with the simplest approach.

35. The inspection process generally follows this pattern:

a. Historical information, such as drawings and previous inspections, is reviewed and recorded before a site visit.

b. A site inspection is conducted and specific visual data are recorded.

c. The inspection data are entered into a personal computer program (MITER).

36. The results of the inspection (e.g., the condition index) are intended to indicate only the existing condition and must be viewed as such. For some cases, it may be necessary to return and conduct a more detailed inspection that might include diving or surveying. This will clearly be the case if a dangerous condition is indicated by the initial inspection. It is beyond the scope of this portion of the project to describe a detailed inspection and evaluation.

Overview of the Inspection Form

37. The inspection form (Figure 9) has been designed to provide flexibility in documenting a variety of field conditions on one standard form. Though there are nine pages in the inspection form, data for the last four can be entered before the initial inspection and do not change for subsequent inspections. These pages need be entered only if the structural condition index is required. The following paragraphs briefly outline and illustrate use of the inspection form.

Historical information

38. Historical information related to the miter lock gate structure is recorded on pages 1 and 2 of the inspection form. This information includes project reference data to identify and locate the specific structure and data to categorize the structure into a particular type and function. The information is also used to sort through the expert rules in the evaluation model (MITER). The recent history of maintenance, modifications, and inspections is also recorded. Finally, a section to record present-day physical conditions of nonessential miter lock gate accessories is also provided.

Field measurements

39. Pages 3 through 5 of the inspection form are for recording field measurements. Several measurements are requested, such as anchorage movements, bearing block gaps and offsets, downstream movements, elevations, dents, cracks, noises, leaks, and corrosion levels. All of these field measurements are used with the expert rules described in Part IV to determine the functional condition index for the gates.

40. Some measurements on these pages are made at four different leaf positions:

a. Recessed. For this case, the leaf is completely open.

b. Near miter. For this position the gates are brought to and held at a location with about 4 ft* between the miter blocks.

c. Miter, 1 ft head. The gates are brought to full miter and the valves are opened to place a nominal 1 ft of head on the gates. The small head closes some gaps and stabilizes the gate during the measurement process.

d. Miter, full head. Full hydraulic head is applied to the gate.

Structural components

41. Information relative to the structural components of specific, horizontally framed, miter lock gate structures is recorded on pages 6 through 9 of the inspection form. The information compiled on these pages provides the basis for an elementary review of the structural adequacy of the leaf. If

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*A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 6.

a vertically framed gate is selected on page 1 of the inspection form, pages 6 through 9 need not be completed. Most of the structural data will be recorded on the form before the site visit; it can be verified during field inspection. The information may be taken from original design drawings, as-built construction drawings, or drawings of field modifications to the structure.

General notes

42. The layout of the inspection form (Figure 9) has been designed to facilitate both the data collection process and the computer input and evaluation. After the initial inspection and computer modeling of a structure, the data on pages 6 through 9 will become relatively permanent and will require only nominal editing of computer data files to keep them current. The first five pages of the inspection form, however, are data pages that must be filled out in the field during the inspection because the information is subject to change. The following pages of this manual duplicate the actual inspection form with entries from an actual test inspection. The side-by-side arrangement of the following pages displays specific explanations adjacent to the entry on the inspection form. Pages 3 through 9 of the inspection form also have notes on how to measure and record critical data.

U.S. ARMY CORPS OF ENGINEERS **PAGE 1**

MITER LOCK GATE STRUCTURE INSPECTION

NAME OF CIVIL WORKS PROJECT:
BARKLEY LOCK AND DAM
UPPER GATE

LOCATION OF CIVIL WORKS PROJECT: (1. Body of water, 2. Nearest town)
1. BARKLEY LAKE
2. GRAND RIVER, KY

INSPECTION DATE: 10/25/88 **INSPECTED BY:** GREIMANN, STECKER, RENS

GATE IDENTIFICATION:

1. Upper gate
2. Lower gate

GATE ID (no.) 1

TYPE OF STRUCTURAL FRAMING PRESENT:

1. Horizontal
2. Vertical

STRUCTURE TYPE (no.) 1

TYPE OF PINTLE:

1. Fixed
2. Floating

PINTLE SYSTEM (no.) 1

TYPE OF SKIN PLATE:

1. Single
2. Double

SKIN TYPE (no.) 1

LENGTH OF LOCK CHAMBER: (ft) 800

WIDTH OF LOCK CHAMBER: (ft) 110

HEIGHT OF GATE LEAF: (ft) 50

GATE WIDTH: (ft) 61.75

PRESENT POOL WATER LEVELS: (ft) UPPER POOL 357.1 **LOWER POOL** 303.3

RECORD LOW WATER LEVEL: (ft) UPPER POOL 354.0 **LOWER POOL** 300.0

RECORD HIGH WATER LEVEL: (ft) UPPER POOL 370.8 **LOWER POOL** 347.3

DO YOU ROUTINELY DEWATER THE LOCK CHAMBER? (Y/N) YES **IF YES, WHAT YEAR WAS THE LOCK LAST DEWATERED?** 1983 **INTERVAL PERIOD?** 5 YRS

CONSTRUCTION DATE: 1966

Figure 9. The inspection form (Sheet 1 of 9)

Page 1 Comments: *Historical or Recordkeeping Data*

Completed before the site inspection and verified or changed during the site inspection.

Data blanks on page 1 prefaced by (No.) ___ must be recorded as numbers.

Enter in NAME the Corps of Engineer Project Title.

Indicate the BODY OF WATER. This may be a river, canal or improved channel, lake, or coastline.

Indicate GATE IDENTIFICATION, TYPE OF FRAMING, TYPE OF PINTLE, and TYPE OF SKIN PLATE by entering the appropriate number in the blank following each name. Refer to the section called "Miter Lock Gate Component Identification" for descriptions and illustrative figures if additional information is required.

Enter nominal LENGTH and WIDTH of lock chamber (e.g., 600 ft. or 1200 ft.)

Enter nominal WIDTH and HEIGHT of gate leaves.

Water level gauge readings referenced to mean sea level. PRESENT and RECORD LOW and HIGH WATER LEVELS are important for reference.

Lock chamber dewatering periods and construction information may be important for reference.

ARE ORIGINAL GATE LEAVES CURRENTLY IN PLACE? (Y/N) YES

IF NOT, IDENTIFY CURRENT GATE LEAF HISTORY: ______

ARE DRAWINGS AVAILABLE FOR GATE LEAVES IN PLACE? (Y/N) YES

ARE THE DRAWINGS INCLUDED WITH THIS FILE? (Y/N) NO

PAST 10 YEAR HISTORY

MAJOR MAINTENANCE, REPAIRS, OR OTHER MODIFICATIONS

	DATE	DESCRIPTION
(1):		
(2):		
(3):		
(4):		

PREVIOUS INSPECTIONS OR STRUCTURAL REVIEWS (attach copies if available)

	DATE	DESCRIPTION
(1):		
(2):		
(3):		
(4):		

TYPE OF FENDER PROTECTION AND CONDITION OF FENDERS:
DENT IN STEEL FENDER

TYPE OF WALKWAY ON GATE LEAF AND CONDITION OF WALKWAY:

OTHER COMMENTS:

Figure 9. (Sheet 2 of 9)

Page 2 Comments: Historical or General Data.

Completed prior to the site inspection and verified or changed during the site inspection.

Gate leaves are sometimes replaced or removed during rehabilitation. It is important for later reference to record the history of the in-place gate.

The next two sections are expanding records and can record up to 10 lines of data. Dates and descriptions are entered on one line as one record. Each record is limited to 70 characters.
Record major MAINTENANCE, REPAIRS, OR OTHER MODIFICATIONS performed on the structure within the last 10 years.

Record PRESENT DAY type (steel or timber) and condition of fender protection.

Record PRESENT DAY type and condition of walkway and hand rails on gate leaf. The items noted in this section are for information only and do not affect the condition index rating of the structure. They are recorded in the inspection file for reference and so that changes can be observed.

FACING DOWNSTREAM AT UPPER GATE, IDENTIFY LEAF AS LAND OR RIVER SIDE

LEFT GATE LEAF = LAND

RIGHT GATE LEAF = RIVER

OPENING AND CLOSING OF GATE LEAVES

	LEFT GATE	% CLOSED	RIGHT GATE	% CLOSED
DO THE DIAGONALS FLAP?	(Y/N) Y	0	(Y/N) Y	0
DOES THE GATE JUMP?	(Y/N) N		(Y/N) N	
IS THERE GATE NOISE?	(Y/N) N		(Y/N) N	
DOES THE GATE VIBRATE?	(Y/N) N		(Y/N) N	

ELEVATIONS OF GATE LEAF

LEFT LEAF	RECESSED	NEAR MITER	MITER 1'HEAD	MITER FULL HEAD
QUOIN	4.46	4.47	4.47	4.47
MITER	4.51	4.54	4.55	4.53

RIGHT LEAF	RECESSED	NEAR MITER	MITER 1'HEAD	MITER FULL HEAD
QUOIN	4.46	4.47	4.47	4.48
MITER	4.53	4.56	4.55	4.54

ANCHORAGE SYSTEM MEASUREMENT (Dim. 1, 2, 3) (Fig. 10)

IS THE CONCRETE CRACKED OR SPALLED AT LOCATION 1?

	LEFT GATE	RIGHT GATE
PARALLEL ARM:	Y/N) N	(Y/N) Y
PERP. ARM:	Y/N) Y	(Y/N) Y

LEFT GATE ARM	DIM.(in)	RECESSED	NEAR MITER	MITER 1'HEAD	MITER FULL HEAD
PARALLEL	1:	0.438	0.438	0.440	0.441
PARALLEL	2:	43.125	43.125	43.125	43.125
PARALLEL	3:	12.875	12.813	12.813	12.813
PERP.	1:	0.324	0.319	0.318	0.320
PERP.	2:	24.5	24.563	24.563	24.5
PERP.	3:	18.563	18.563	18.563	18.563

RIGHT GATE ARM	DIM.(in)	RECESSED	NEAR MITER	MITER 1' HEAD	MITER FULL HEAD
PARALLEL	1:	0.345	0.347	0.348	0.349
PARALLEL	2:	43.375	43.375	43.375	43.313
PARALLEL	3:	12.625	12.563	12.563	12.5
PERP.	1:	0.193	0.193	0.194	0.199
PERP.	2:	20.25	20.25	20.25	20.156
PERP.	3:	21.75	21.813	21.875	21.875

Figure 9. (Sheet 3 of 9)

Page 3 Comments: Field data.

Completed at site inspection.

Record the orientation of the lock chamber relative to the land by facing downstream and identifying the left and right gate as the land or river side.

OPENING AND CLOSING OF GATE LEAVES: Observation of the gate leaves during operation (opening and closing) is a good indicator of problems. If the diagonals make a flapping noise, or if the gate vibrates (chatters), indicate the approximate positions at which the noise or vibration occurs. Similarly, record the occurrence and positions of any unusual noises or jumping movement.

ELEVATIONS OF GATE LEAVES: When the gate leaves are in the recessed position (1), measure the miter and quoin elevations of each leaf. A specific point should be identified and marked at each of the four locations, usually on the walkway, near the quoin and miter. Measurement should be made with a rod and level. Repeat this process for three additional positions: (2) near miter (approximately 4 ft from miter), (3) miter with 1 ft of head in chamber, and (4) mitered with full head. Measurement should be recorded and interpolated to nearest 0.005 ft, (e.g., 1.115).

ANCHORAGE SYSTEM MEASUREMENT: The parallel and perpendicular anchorage arms are parallel and perpendicular, respectively, to the lock chamber. Indicate the presence of excessive concrete cracking at location 1 where the anchorage enters the concrete (Figure 10). Excessive concrete spalling may indicate that a displacement occurred at this location at some point in time and may or may not show up at a current measurement. Small hairline cracks, probably caused by thermal expansion or contraction of the concrete, should be ignored in this analysis.

Measurements must be made on both parallel and perpendicular anchorage arms at four leaf positions: (1) recessed, (2) near miter (approximately 4 ft from miter), (3) mitered with 1 ft of head, (4) and mitered full head. Dimension 1 can be measured with a dial gage attached to a magnet. The magnet is placed on the steel of the anchorage arm with the dial gage plunger pushing on the concrete wall. Displacements should be recorded to 0.001 in.

Dimension 2 can be measured with a ruler or tape measurement between two scribe marks. One scribe mark should be on each side of the length adjustment device (turn buckle, wedges, etc.). Connection pins should be between the two scribes. As noted in Chapter 1, some anchorages have an additional pin. Measurement 2 should be made across this pin also. Measurement 2 must include movement in all linkage pieces except the concrete/steel interface (Dimension 1) and at the gudgeon pin (Dimension 3). In some cases, the measurement cannot be made between two scribe lines because of geometrical interferences. In these cases, the authors have contrived assemblages of C clamps and straps of steel to obtain the change in length between the two points.

Dimension 3 is also measured with a ruler or a tape measure. In the simplest case, the measurement is between a scribe point on the gudgeon pin arm and a point at the center of the gudgeon pin. The measurement is intended to detect wear in the pin and/or bushing. In most cases, the simple approach is not available because of geometric interferences. Often it is necessary to project the point on the gudgeon pin area upward, above interferences with the leaf or other obstructions. C clamps and strap steel have been used for this. Often the center of the gudgeon pin is not accessible. Steel plates may have to be removed. Sometimes a grease pipe is at the pin center. Sometimes a bolt or pipe can be screwed into the center, if threads are present, to extend this measurement point upward. Ingenuity is often required for this important measurement.

MITER AND QUOIN BEARING MEASUREMENTS

OFFSET OF MITER BLOCKS WITH GATES AT MITER (1'HEAD), (DIM. 4, 5) (FIG. 11.)

LOCATION	MEASUREMENT (in.)	DISTANCE BELOW TOP GIRDER (ft)	GATE DOWNSTREAM
TOP:	0.25	3.75	(L/R) L
DSWL:	0	24.0	(L/R) L

(DSWL = DOWNSTREAM WATER LEVEL WITH 1' HEAD ON GATES)

GAP BETWEEN BEARING BLOCKS WITH GATES AT MITER (1'HEAD), (DIM. 6, 7) (FIG. 12.)

LOCATION	MEASUREMENT (in.),	DISTANCE BELOW TOP GIRDER (ft)
LEFT QUOIN @ TOP:	0	6
LEFT QUOIN @ DSWL:	0.0157	26.0
RIGHT QUOIN @ TOP:	0	6.0
RIGHT QUOIN @ DSWL:	0.0396	26.0
MITER @ TOP:	0	3.75
MITER @ DSWL:	0	26.0

LONGITUDINAL POSITION OF MITER POINT (DIM. 8) (FIG. 12.)

LOCATION	MEASUREMENT (in.) 1' HEAD	MEASUREMENT (in.) FULL HEAD	DISTANCE BELOW TOP GIRDER (ft)
TOP:	4.875	4.5	3.0
DSWL:	0.875	1.25	24.0

LOCK CHAMBER FILLING (OR EMPTYING)

DOES THE GATE VIBRATE? LEFT GATE: (Y/N) Y
RIGHT GATE: (Y/N) Y

DOES A LEAK FOLLOW THE RISING (OR EMPTYING) WATER LEVEL AND THEN CLOSE AGAIN AS THE WATER CONTINUES TO RISE (EMPTY)?
LEFT QUOIN: (Y/N) N
MITER : (Y/N) N
RIGHT QUOIN: (Y/N) N

DOES THE GAP BETWEEN MITER BLOCKS CHANGE? (Y/N) Y

IF YES, SELECT FROM THE FOLLOWING CHOICES THE MOST ACCURATE DESCRIPTION OF THE CHANGE. (NO.) 4

1. TOP GAP INITIALLY OPEN BUT CLOSES UNDER FULL HEAD.
2. TOP GAP OPENS WIDER BUT CLOSES UNDER FULL HEAD.
3. TOP GAP OPENS AND REMAINS OPEN.
4. TOP OF MITER IS CLOSED BUT GAP OPENS BETWEEN WATER LINE AND TOP.
5. TOP OF MITER IS CLOSED AND GAP BETWEEN WATER LINE AND TOP CLOSES.

ESTIMATE THE MAXIMUM WIDTH OF GAP (IN.) 0.3
ESTIMATE THE LOCATION OF THE MAXIMUM GAP FROM TOP GIRDER (FT.) 14.0

Figure 9. (Sheet 4 of 9)

Page 4 Comments: Field data.

MITER BLOCK OFFSET: The offset of miter blocks at the top of the gate, Dimension 4, and at the downstream water level (DSWL), Dimension 5, along with the vertical distance from the walkway to each measurement can be made with a ruler and tape. See Figure 11 for illustration of miter offsets. The gate leaves should be in the mitered position with 1 ft of head in the chamber to stabilize the gates. In addition, record the relative orientation of the leaves by indicating which gate is farther downstream, left (L) or right (R), at each measurement.

BEARING BLOCK GAPS: Bearing blocks include the land quoin (LQ), river quoin (RQ) (Dimension 6, Figure 12), and the miter (Dimension 7, Figure 12). The gap measurement between bearing blocks at the top of the gate and at the downstream water level (DSWL) along with the vertical distance from the top girder to each measurement can be made with a feeler gauge or ruler and a tape measure. The gate leaves should be in the mitered position with one foot of head in the chamber to stabilize the gates.

LONGITUDINAL POSITION OF MITER POINT: The longitudinal position of the miter point at the top of the gate and at the downstream water level (DSWL) along with the vertical distance from the top girder to each measurement are recorded. To make this measurement, the authors have attached rulers near the miter block on a leaf at both the top and the DSWL. The rulers are oriented such that the readings increase downstream. A transit is located on the lock wall such that both rulers can be read over the edge of the wall. The vertical cross hair establishes a vertical plane from which the readings are made. These measurements should be made with the gate leaves closed with 1 foot of head in the chamber and at full head.

LOCK CHAMBER FILLING OR EMPTYING: As the lock chamber is filling, water passing underneath the gate may cause the seals to flutter (vibrate). Placing your ear near the walkway railing will amplify this noise as the gate vibrates.

Changing characteristics of the gaps may help an experienced engineer identify the cause and/or magnitude of bearing block problems. A leak between the blocks indicates a gap. If the leak stops as the water rises or falls, the gap has closed. If a LEAK FOLLOWS THE RISING (OR EMPTYING) WATER LEVEL AND THEN CLOSES AGAIN, record this occurrence. Chapter 4 discusses the implications of changing gaps.

For the visible portion of the gap above the water, answer whether THE GAP BETWEEN MITER BLOCKS CHANGES? If the answer is YES, provide the most accurate description of the gap opening and closing chances. Also, estimate the MAXIMUM WIDTH OF GAP and its LOCATION.

OBSERVATIONS FROM BOAT

CORROSION AT SPLASH ZONE (LEVEL 0,1,2,3,4, or 5)

	LEFT GATE (LG) UPSTREAM	LEFT GATE (LG) DOWNSTREAM	RIGHT GATE (RG) UPSTREAM	RIGHT GATE (RG) DOWNSTREAM
SKIN:	/	/	/	/
GIRDER:	/	/	/	/
INTERCOSTAL:	/	/	/	/

DENTS -- SKIN PLATE (S), GIRDERS (G), or INTERCOSTALS (I)

	GATE L or R	COMPONENT S, G, or I	LOCATION, DISTANCE FROM: TOP GIRDER (ft)	QUOIN (ft)	SIZE (ft) HEIGHT	WIDTH
(1):	R	G	15.0	58.0	1.0	0.5
(2):						
(3):						
(4):						
(5):						

CRACKS -- SKIN PLATE (S), GIRDERS (G), or INTERCOSTALS (I)

	GATE L or R	COMPONENT S, G, or I	LOCATION, DISTANCE FROM: TOP GIRDER (ft)	QUOIN (ft)	SIZE (ft) LENGTH
(1):					
(2):					
(3):					
(4):					
(5):					

BEARING BLOCK LEAKS @ LEFT (L), MITER (M), or RIGHT (R)

	TYPE -- L,M,R	DISTANCE FROM TOP GIRDER (ft)	LENGTH (ft)
(1):	R	40.0	0.5
(2):	M	28.0	0.25
(3):			
(4):			
(5):			

SKIN LEAKS @ LEFT GATE (L), RIGHT GATE (R)

	GATE L or R	TYPE (H)ORIZ. OR (V)ERT	SHORTEST DISTANCE FROM TOP GIRDER (ft)	QUOIN (ft)	LENGTH (ft)
(1):					
(2):					
(3):					
(4):					
(5):					

BOILS @ LEFT GATE (L), RIGHT GATE (R), MITER (M)

	TYPE (L,R, or M)	DISTANCE FROM QUOIN (ft)
(1):	M	61.0
(2):	L	40.0
(3):		
(4):		
(5):		

Figure 9. (Sheet 5 of 9)

Page 5 Comments: Field Data.

CORROSION AT SPLASH ZONE: The corrosion of the skin plate, girders, and intercostals is rated in a visual subjective manner. Refer to Part IV for more details on the rating scheme. Selection of the corrosion level observed at the splash zone (air/water interface) is made by comparing the observed condition to the standards in Table 4 and/or visually comparing it to the photographs in Figure 25. There are five levels of deterioration. Level 0 is new or nearly equal to new. Upstream and downstream levels are recorded.

DENTS: The location and dimension of skin plate, intercostal, and girder dents are determined by a ruler or tape measure. The coordinates of the dent are taken as the distance from the walkway and quoin corresponding to the specific gate leaf.

CRACKS: The location and length of skin plate, intercostal, and girder cracks is made with a ruler or tape measure. The coordinates of the crack are taken as the distance from the top girder and quoin on the specific gate leaf to the nearest point of the crack.

BEARING BLOCK LEAKS: The location and length of the left quoin (L), right quoin (R), or miter (M), bearing block leaks are measured with a tape measure. The location of the leak is determined as the distance from the top girder to the top of the leak. A leak of length 0 indicates a point or local leak.

SKIN LEAKS: The location and dimension of skin plate leaks are measured by a tape measure. Two types of skin plate leaks usually exist: horizontal (H) indicates a horizontal leak and vertical (V) indicates a vertical leak. The coordinates of the leak are taken as the distance from the top girder and quoin to the top of the leak. The corresponding gate leaf, right (R) or left (L), is also recorded.

BOILS: The existence of boils from below the water surface on the right gate (R), left gate (L), or at the miter (M) will be noted by location (distance from the quoin).

Calculation date: 10/25/88 Calculated by: RENS

REQUIRED OVERALL VERTICAL GEOMETRY --(Fig. 13)

Positive elevation of sill above any datum, ELSILL (ft): 333.0
Sill to bottom of skin plate, GBOT (ft): 0.75
Sill to overflow elevation at top of gate, GTOP (ft): 44.75

REQUIRED OVERALL LEAF GEOMETRY -- (Fig. 13)

Leaf between contact points, GLENG (ft): 62.0
Gate leaf slope, GSLOPE (ft): 3
Working line to downstream edge of girder webs, GWORKL (ft): 0.313
Quoin contact point to gudgeon pin, GQUOIN (ft): 1.98
Working line to gudgeon pin (positive when contact point is downstream from gudgeon pin), GPIN1 (ft): 1.25

COMMON GIRDER GEOMETRY DIMENSIONS --(Fig. 13)

Girder web depth, GWEBD (in): 82.0
Quoin contact point to center of nearest end diaphragm along working line, DQPED (in): 117.25
Center of end diaphragm at miter end of gate to miter contact point along working line, DEDMP (in): 117.25
Bottom girder downstream flange extension below web centerline, BGDFD (in): 3

GIRDER ELEVATIONS -- (Fig. 13)

Number of girders in the gate leaf, NGIRDS: 11

Girder Number, NGIRD	Vertical distance above sill, VD (ft)
1	44.75
2	40.75
3	36.25
4	31.75
5	27.25
6	22.75
7	18.25
8	13.75
9	9.25
10	5.25
11	0.75

Figure 9. (Sheet 6 of 9)

Page 6 Comments: Structural Components Data

Complete before the site inspection and verify or change data during the site inspection. Data must be recorded in the indicated units.

REQUIRED OVERALL VERTICAL GEOMETRY: Provide the overall vertical leaf dimensions based on the available design drawings. ELSILL is the positive elevation of the sill above any datum, usually referenced to mean sea level. GBOT is the clear space between the sill and the bottom of the gate, and GTOP is the distance from the sill to the overflow elevation (top of skin plate). See Figure 13 for illustration.

REQUIRED OVERALL LEAF DIMENSIONS: Provide the overall leaf dimensions based on the available design drawings. GLENG is the length of leaf between quoin and miter contact points. GWORKL is the distance from the working line to the downstream edge of the girder web. GQUOIN is the distance along the gate leaf working line from the quoin contact point to the gudgeon pin, and GPIN1 is the distance from the working line to the gudgeon pin. (See Figure 13.)

GIRDER COMMON DIMENSIONS: Provide the overall girder dimensions based on the available design drawings. GWEBD is the depth of the web plate or the clear distance between girder flanges. DQPED is the distance along the gate leaf working line from the quoin contact point to the end diaphragm. DEDMP is the distance along the gate leaf working line from the miter contact point to the end diaphragm. DQPED and DEDMP are usually equal. BGDFD is the bottom-girder downstream flange, downward extension below the web centerline. (See Figure 13.)

GIRDER WEB ELEVATIONS: Indicate the number of girders, NGIRDS, and provide the girder number, NGIRD, and the vertical distance, VD, above the sill, ELSILL for each girder. (See Figure 13.)

NOTE: The information furnished on pages 6 through 9 serves as input to the CMINV module (see Part III). The notation is identical to the CMINV documentation (US Army Corps of Engineers 1988b, US Army Corps of Engineers 1988a).

GIRDER DIAPHRAGM SPACING -- (Fig. 13)

Top girder of similar pnl NPANLI	Bottom girder of similar pnl NPANLN	Spaces between end diaphragms NDS	Itrcstl spaces btwn adj dphrgms NIS
1	10	4	6
10	11	8	3

DEAD AND LIVE LOADS:

Additional dead load, including ice, mud walkway, gusset plates, etc,
ADEAD (lbs.): 6642
Quoin contact point to centroid of ADEAD along working line,
XDEAD (ft): 31.0
Downstream edge of girder web to controid of ADEAD, ZDEAD (in.): 0
Bouyancy force acting on dry weight of gate, ABUOY (lbs.): 0
Quoin contact point to centroid of ABUOY along working line,
XBOUY (ft.): 0
Downstream edge of girder web to centroid of ABOUY, ZBOUY (in.): 0
Concentrated live load, including walkway and bridgeway,
ALIVE (lb.): 0

REQUIRED WATER ELEVATIONS -- (FEET ABOVE ELSILL) (Fig. 14)

Elevation of upper pool,	ELUP (ft):	375.0
Elevation of lower pool,	ELLP (ft):	302.0
Full submerge elevation,	ELFS (ft):	378.125
Operating water elevation,	ELOW (ft):	375.0

STEEL YEILD STRENGTH (KSI):

Miscellaneous Steel yield strength 36.0

Webs	Flanges	Skin	Stiffeners	Intercostals	Quoin	Diaphragms
36.0	36.0	36.0	36.0	36.0	36.0	36.0

Figure 9. (Sheet 7 of 9)

Page 7 Comments: Structural Components Data

GIRDER DIAPHRAGM SPACING: Provide the girder diaphragm spacing on the basis of the available design drawings. For each similar group of skin plate panels, record the top girder, NPANLI, and the bottom girder, NPANLN, along with the number of diaphragm spaces between end diaphragms, NDS, and the number of intercostal spaces, NIS, between adjacent diaphragms. (See Figure 13.)

DEAD AND LIVE LOADS: Provide the dead and live load on the basis of the available design data. ADEAD is additional concentrated dead load (in addition to girders, skin plate, intercostals, etc.), ice, mud, walkway, intermediate stiffeners, gusset plates, etc., applied at (1) XDEAD, the distance along the working line measured from the quoin contact point, and (2) ZDEAD, the distance from the downstream edge of the girder web. ABUOY is the concentrated buoyancy force acting on the dry weight of the gate applied at (1) XBUOY, the distance along the working line measured from the quoin contact point, and (2) ZBUOY, the distance from the downstream end of the girder web. ALIVE is the concentrated live load including the walkway and bridgeway. (See Figure 13.)

REQUIRED WATER ELEVATIONS: Record the elevations of the upper pool, ELUP, the lower pool, ELLP, the full submergence elevation, ELFS, and the operating water elevation, ELOW. The elevations are referenced to the same datum as ELSILL, the elevation of the sill. This may duplicate information on page 1. See Figure 14 for illustration of water elevations.

YIELD STRENGTH: Several yield strengths are used in miter lock gates. Record the yield strengths of the components listed and a miscellaneous yield strength for all of the steel components not specifically listed.

GIRDER WEB THICKNESSES (IN.) (Fig. 15)

Groups of similar girders: Top girder NGIRDI	Groups of similar girders: Bottom girder NGIRDN	Web end zone thickness GWET	Web center zone thickness GWCT
1	1	0.5	0.5
2	7	0.5	0.5
8	9	0.625	0.625
10	10	0.75	0.75
11	11	1.0	1.0

GIRDER FLANGES, UPSTREAM (IN.) -- (Fig. 15)

Groups of similar girders: Top Number NGIRDI	Groups of similar girders: Bottom Number NGIRDN	Upstream flange widths: GUFEW	GUF34W	GUF4CW
1	5	9.0	9.0	9.0
6	6	10.5	10.5	10.5
7	7	12.0	12.0	12.0
8	8	12.0	12.0	12.0
9	10	15.0	15.0	15.0
11	11	16.0	16.0	16.0

Upstream flange thickness: GUFET	GUFCT	Upstream flange cover plate: Distance from quoin GUCPX	Width GUCPW	Thickness GUCPT
1	1	0	0	0
1	1	0	0	0
1	1	0	0	0
1.25	1.25	0	0	0
1.25	1.25	0	0	0
2	2	0	0	0

GIRDER FLANGES, DOWNSTREAM (IN.) -- (Fig. 15)

Groups of similar girders: Top Number NGIRDI	Groups of similar girders: Bottom Number NGIRDN	Downstream flange widths: GDFEW	GDFCW
1	1	9	9
2	5	9	9
6	6	9.5	9
7/8	7/8	10.1/9.5	9/9
9/11	10/11	10.1/10.4	9/12

Downstream flange thickness: GDFET	GDFCT	Downstream flange cover plate: Distance from quoin GDCPX	Width GDCPW	Thickness GDCPT
0.75	0.75	0	0	0
0.75	0.75	0	0	0
0.75	0.75	0	0	0
0.75/1.0	0.75/1.0	0/0	0/0	0/0
1.0/1.0	1.0/1.0	0/0	0/0	0/0

Figure 9. (Sheet 8 of 9)

Page 8 Comments: Structural Components Data.

GIRDER WEB THICKNESSES: Provide the girder web thicknesses on the basis of the available design drawings. For each similar group of girder web thicknesses, record the top girder, NGIRDI, and the bottom girder, NGIRDN. In addition, the end zone web thickness, GWET, and the center zone web thickness, GWCT, must be recorded. See Figure 15 for illustration of girder web thicknesses.

GIRDER FLANGES, UPSTREAM: Provide the upstream flange widths and thicknesses on the basis of the available drawings. For each similar group of upstream girder flanges, record the top girder, NGIRDI, and the bottom girder, NGIRDN, along with the end zone width, GUFEW, and thickness, GUFET, from the girder end to the corner splice. Also record the flange width from the corner splice point to the flange splice point, GUF34W, and the flange width from the flange splice point to the girder centerline, GUF4CW. The flange thickness, GUFCT, is usually the same in these two regions and must be recorded. In addition, the upstream flange cover-plate distance from the quoin, GUCPX, width, GUCPW, and thickness, GUCPT must be recorded. A zero in the last three entries indicates that no cover plate is present. (See Figure 15.)

GIRDER FLANGES, DOWNSTREAM: Provide the upstream and downstream flange widths and thicknesses based on the available drawings. For each similar group of upstream girder flanges, record the top girder, NGIRDI, and bottom girder, NGIRDN, along with the end zone width, GDFEW, and thickness, GDFET, from the girder end to the splice point. Also record the width, GDFCW, and the thickness, GDFCT, from the splice point to the downstream cover plate location, CDCPX, width, GDCPW, and thickness, GDCPT. A zero in the latter three of these entries indicates no cover plate is present. (See Figure 15.)

GIRDER FLANGE COORDINATES (FT) -- (Fig. 15)

Groups of similar girders: Top no. NGIRDI	Bottom no. NGIRDN	Flange splice distance from quoin: Upstream GUFX4	Downstream FDFX5
1	11	117.25	144

GIRDER WEB STIFFENERS (IN.) -- (Fig. 15)

Groups of similar girders: Top no. NGIRDI	Bottom no. NGIRDN	No. trans. stffnr spcs btwn intrmdt dphr NGWTS	No. of long stffnr pairs NGLS
1	9	0	1
2	9	2	1
10	10	1	1
11	11	0	1

Longitudinal stiffener geometry

Stiffener number 1 GLS1D	Width GLS1W	Thcknss GLS1T	Stiffener number 2 GLS2D	Width GLS2W	Thcknss GLS2T	Stiffener number 3 GLS3D	Width GLS3W	Thcknss GLS3T
41	-4	0.5	0	0	0	0	0	0
41	-4	0.5	0	0	0	0	0	0
41	-5.5	0.5	0	0	0	0	0	0
41	-5.5	0.5	0	0	0	0	0	0

INTERCOSTAL AND SKIN PLATE GEOMETRY (IN.) -- (Fig. 15)

Groups of similar intercostals: Top girder no. NPANLI	Bottom firder no. NPANLN	Skin plate thickness SPT
1	6	0.375
7	11	0.5

Depth (perp to skin) ODI	Stem thcknss STEMT	Flng width FWI	Flng thcknss FTI
6	0.5	0	0
7	0.5	0	0

Figure 9. (Sheet 9 of 9)

GIRDER FLANGE COORDINATES: Provide the girder flange splice coordinates on the basis of available design drawings. For each similar group of girder flange splice coordinates, record the top girder, NGIRDI, and the bottom girder, NGIRDN, along with the upstream flange splice coordinates, GUFX4, and the downstream flange splice coordinate, GDFX5. The coordinate is measured from the quoin contact point as illustrated in Figure 15.

GIRDER WEB STIFFENERS: Provide the girder web stiffener information on the basis of the available design drawings. For each similar group of girder web stiffeners, record the top girder number, NGIRDI, and the bottom girder number, NGIRDN. Also, record the number of girder web transverse (vertical) stiffener spaces, NGWTS, between adjacent intermediate diaphragms, and the number of longitudinal stiffeners, NGLS, between girder flanges. In addition, indicate for each of the longitudinal web stiffeners: (1) the distance from the downstream web edge, GLS1D, (2) the width, GLS1W, and (3) the thickness, GLS1T. A zero entry indicates no stiffener present, and a negative entry for a longitudinal web stiffener width indicates stiffeners on only one side of the web. (See Figure 15.)

INTERCOSTAL AND SKIN PLATE GEOMETRY: Provide the intercostal and skin plate geometry on the basis of the available design drawings. For each similar group of panels, record the top girder, NPANLI, and the bottom girder, NPANLN, and the corresponding skin plate thickness, SPT, within this region. In addition, record (1) the overall depth of the intercostal, ODI (including the flange thickness), (2) the thickness of the perpendicular leg touching the skin plate, STEMT, (3), the width of the angle parallel to the skin plate (flange), FWI, and (4) the flange thickness of the intercostal, FTI. (See Figure 15.)

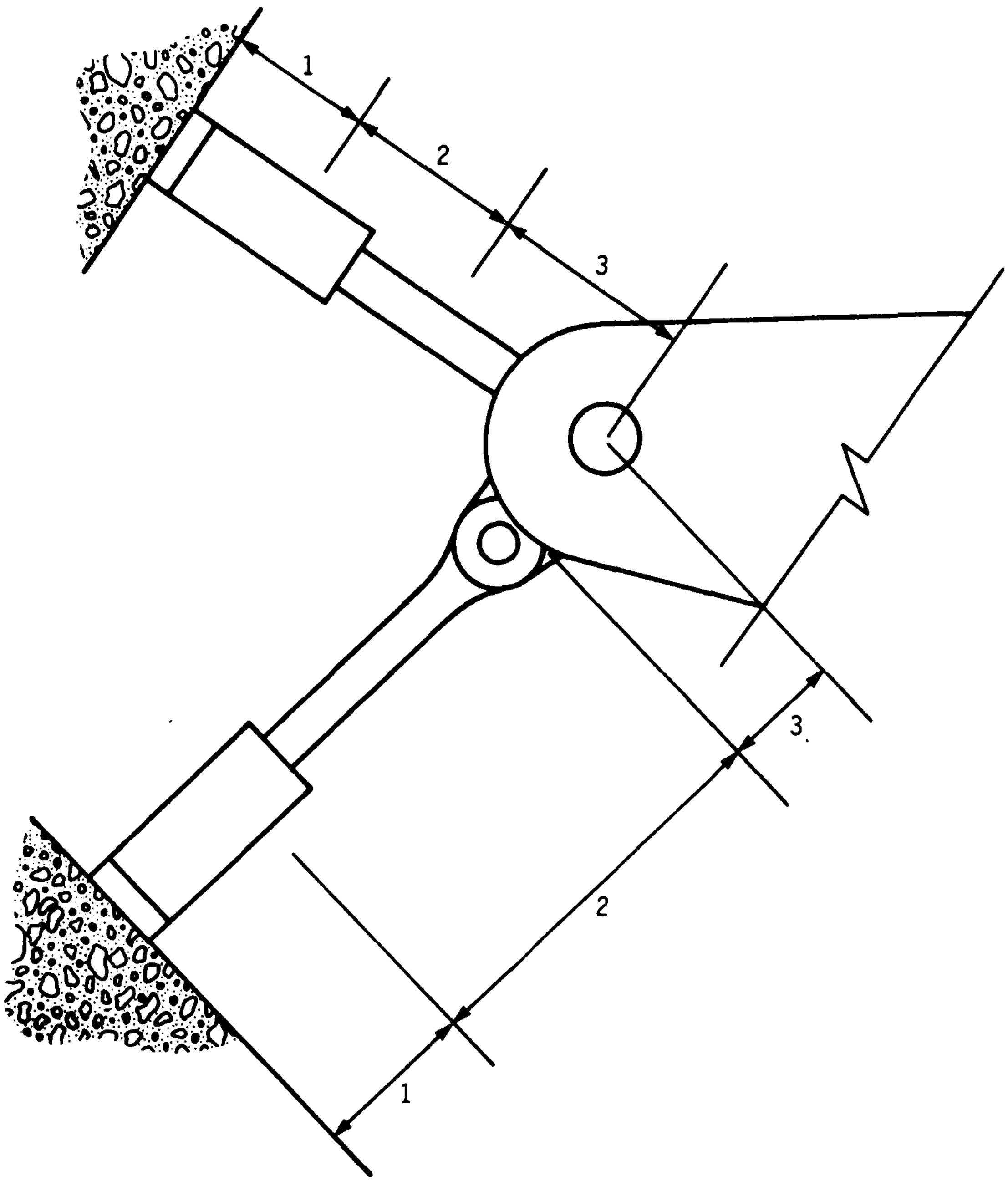


Figure 10. Double linkage pin assembly (dimensions)

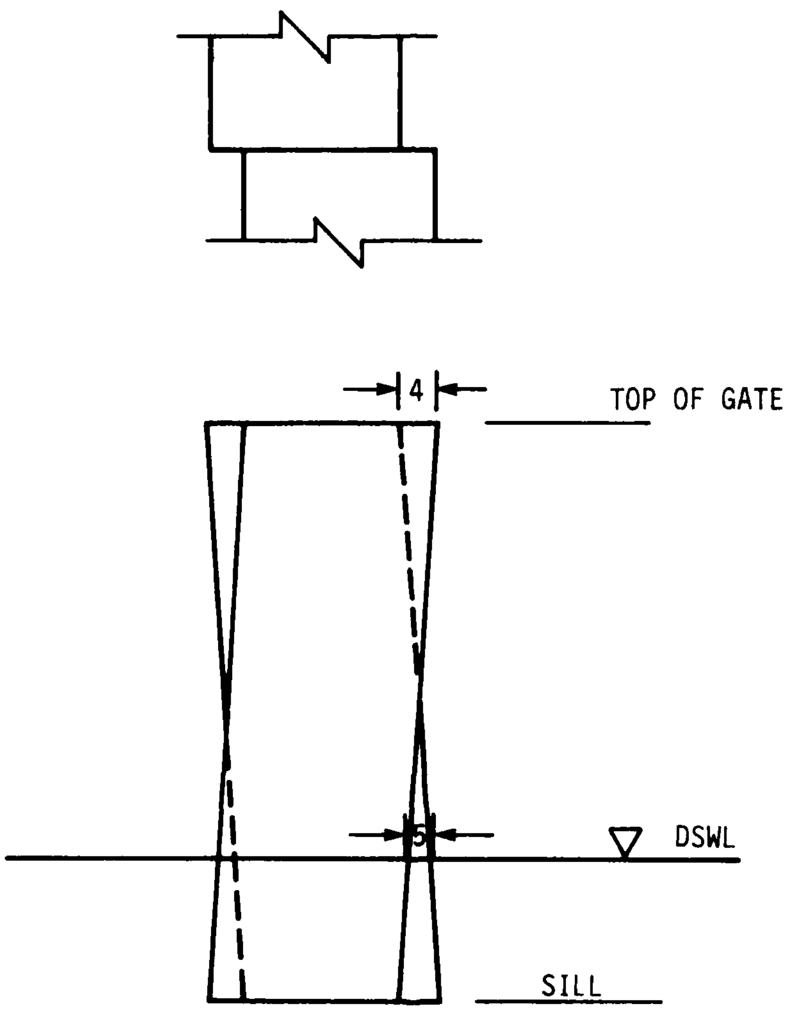


Figure 11. Miter block offset

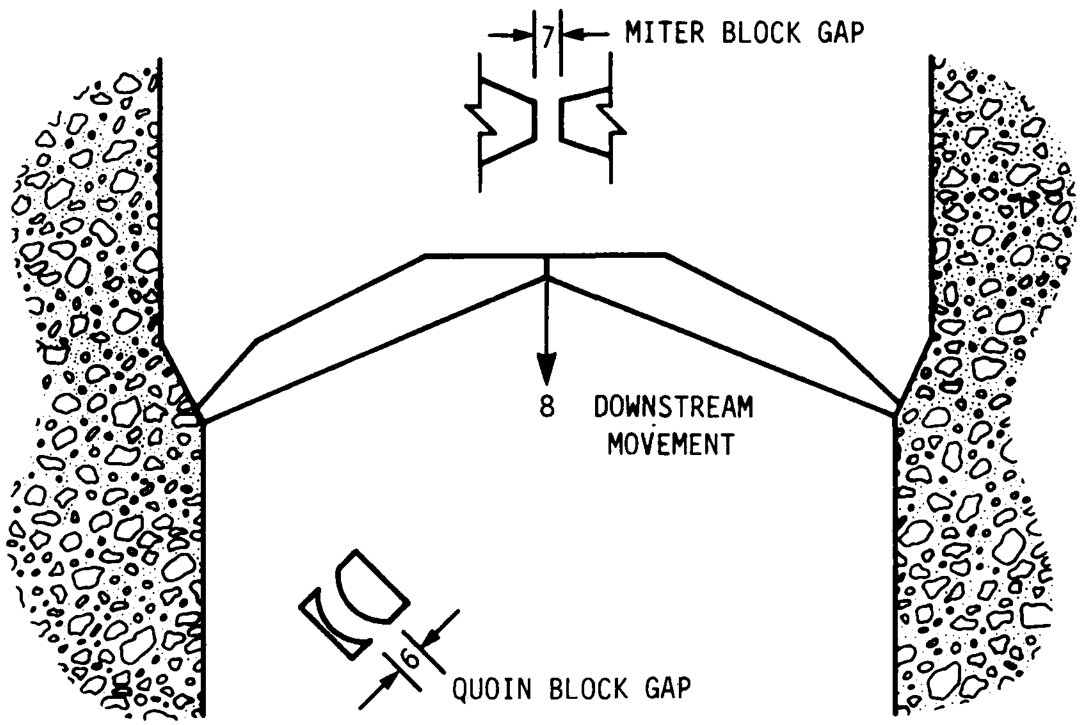


Figure 12. Gaps, downstream movement

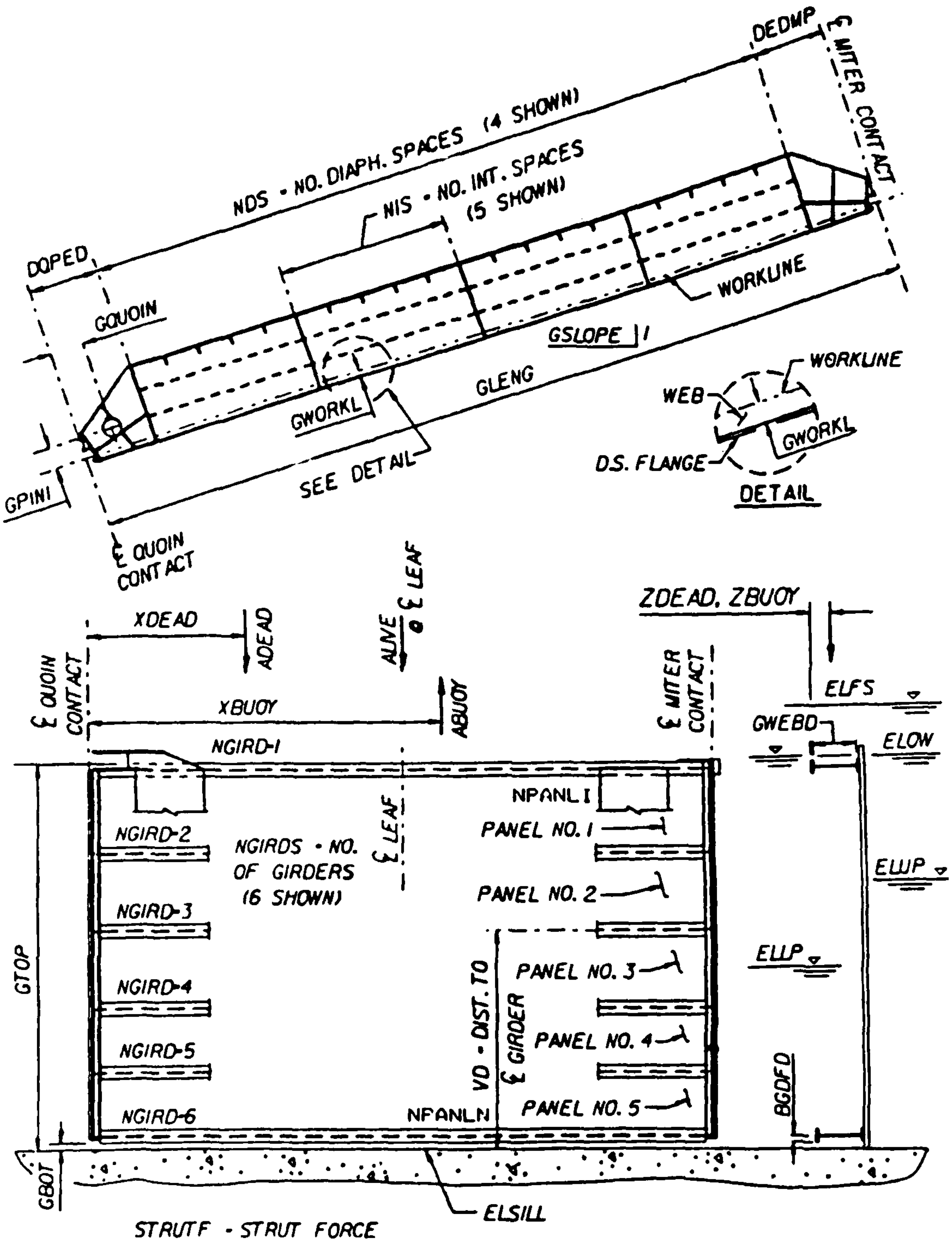


Figure 13. Leaf geometry

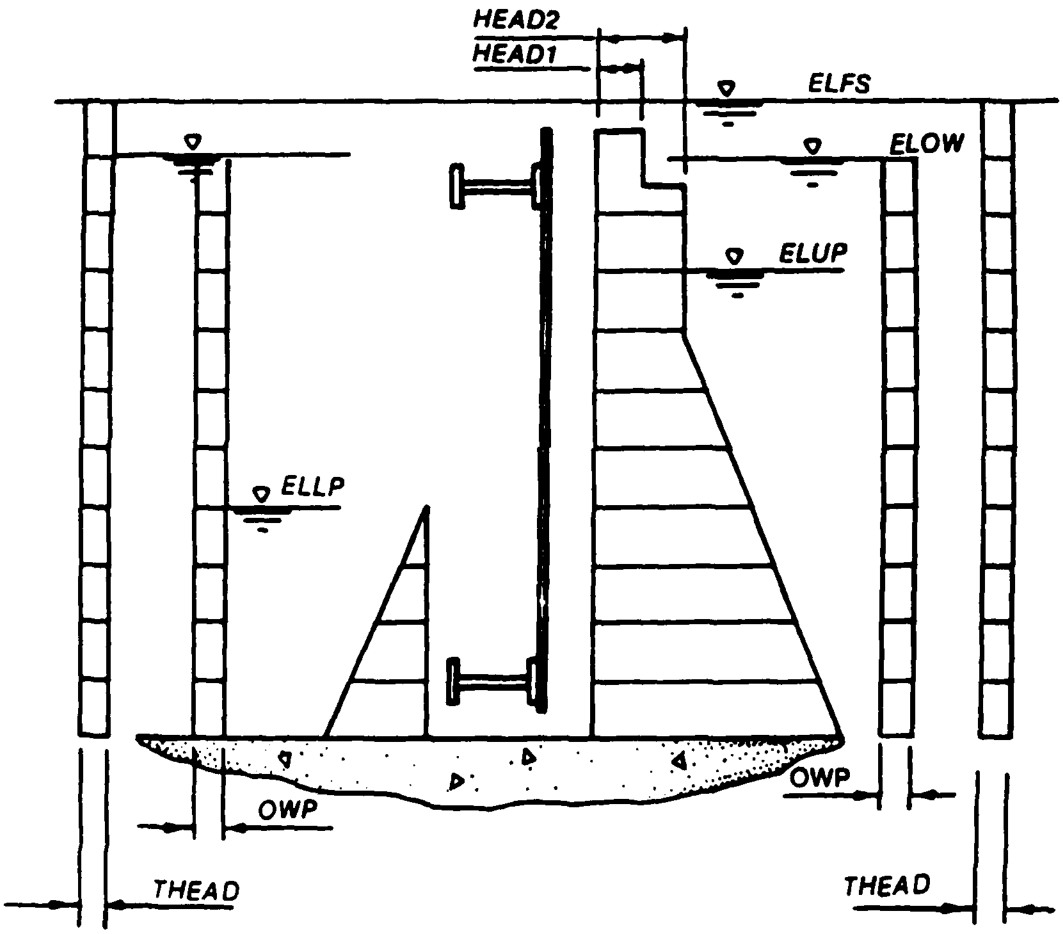


Figure 14. Water elevations (computer input)

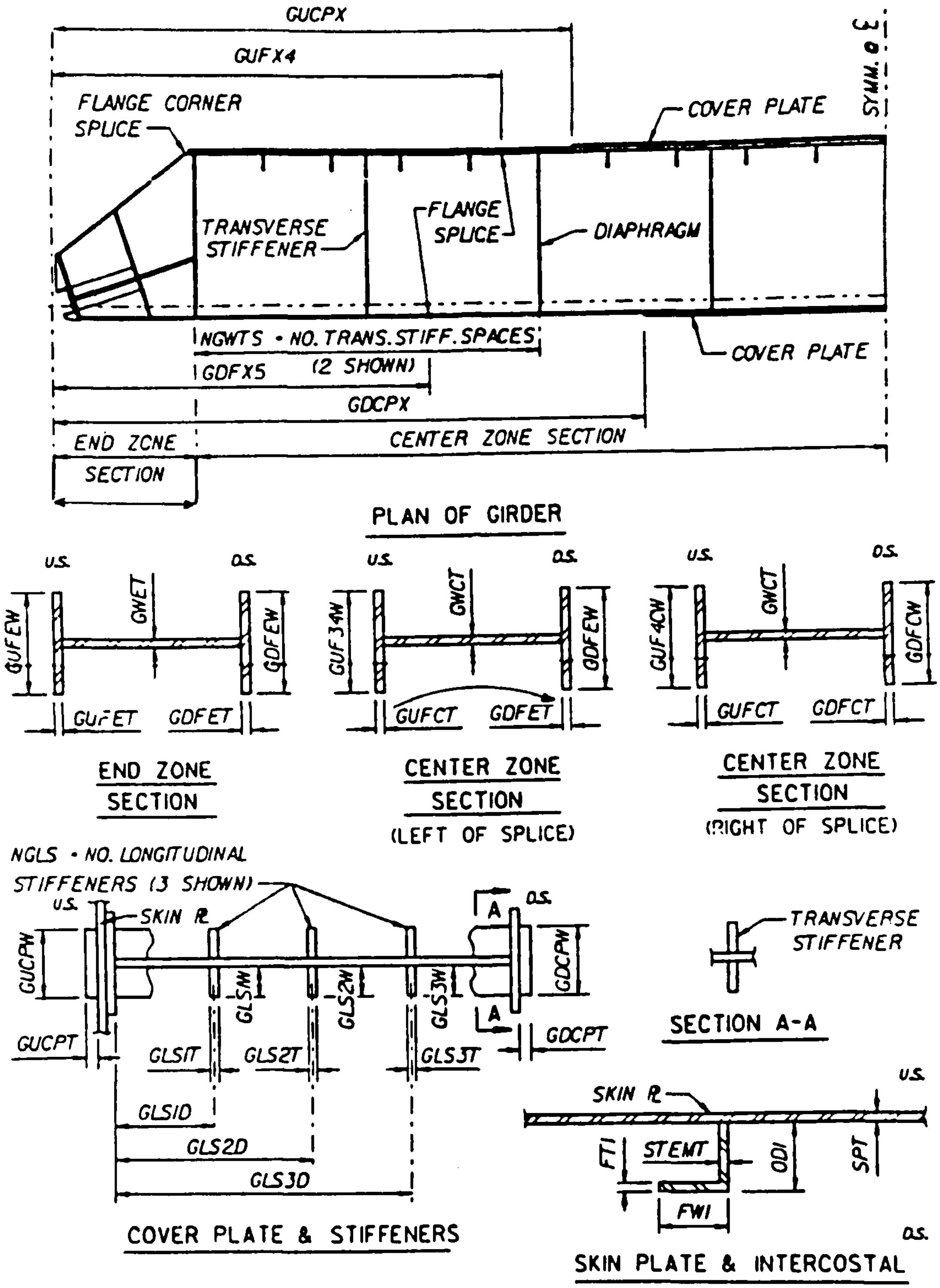


Figure 15. Component geometry

PART III: STRUCTURAL CONDITION INDEX

43. Structural safety often refers to potential loss of life or significant property damage. If a structure is unsafe, it is in danger of collapse. Structural safety has traditionally been measured by a factor of safety. Hence, uncertainties in loading and structural strength (i.e., emergency conditions) are accounted for by selecting an appropriately high factor of safety to ensure a sufficient margin between the applied loads and the structural resistance. For example, the design criteria for miter lock gates typically require a factor of safety of two.

44. In this project, a structural condition index is defined as a measure of the safety of the structure or risk of failure of the structure. It is based directly on the calculation of the factor of safety. The factor of safety calculation is often perceived as a fairly rational, objective process. However, many simplifying assumptions must be made. In fact, the structural analysis of a miter lock gate involves many subjective decisions. Fortunately, many of the assumptions have been standardized. Since this is the case, the factor of safety and, hence, the structural condition index are, at least, reasonably repeatable (relative to the functional condition index discussed in Part IV).

Structural Analysis

45. A basic part of the structural safety evaluation is a structural analysis. As with all structural analyses, several assumptions must be made. In this work, the basic assumption is that miter lock gates behave in the manner for which they were designed. With this assumption, the US Army Corps of Engineers design manuals, 1963 and 1984, are used for the structural analysis. These sources are supplemented by Corps computer program, CMITER (US Army Corps of Engineers, 1987), that implements these rules for the horizontally framed gate.

46. Horizontally framed gates generally provide a more rigid structure than vertically framed gates. For shallow gate leaves up to a height-to-width ratio of one, the vertically framed gate requires less material and weighs less. The horizontally framed gate is used on higher lift locks. Horizontally framed gates are used most frequently with the exception of the Mississippi River system. Approximately 95 percent of miter gates in service, and all new construction, are horizontally framed. Moreover, CMITER analyzes only horizontally framed gates; thus, the structural analysis in this study is concerned with horizontally framed gates only.

47. The structural analysis module of CMITER, called CMINV, interfaces with the inspection forms to perform a structural analysis of several

components on the horizontally framed gate leaf. The inspection form, pages 6 through 9, serve as the input to CMINV, and are described in Part II. Because the input and output of CMINV is long and detailed, the structural analysis in this project has been limited to three significant components: girders, intercostals, and skin plate.

48. A computer program (MTR) has been written by project personnel to post-process the CMINV output file by calculating the factors of safety and condition indexes of the three selected components. The computer selects the worst case in terms of the lowest condition index of the three components for each of five load cases.

Loads

49. The loads normally applied to miter lock gates consist of water pressure, operating loads (opening and closing), boat impact, and dead and live loads. Water pressure is produced by pool differential on the sides of the gate as the lock is filled or emptied. Operating loads are the result of the strut arm force and water resistance to the moving leaf as it is opened and closed. Boat impact load is the force produced by barges and vessels colliding with the gate. Dead load includes ice, mud, etc.; live load includes loads acting on the bridgeway and walkway. Abnormal or emergency loads include any of the normal loads in addition to earthquake loads, increased water loads (dewatering for maintenance), obstruction condition, and temporal hydraulic loads (temporal head) below the full submergence elevation (a pulse load or a wave, see Figure 16).

50. The load types described above are grouped into six load cases.

Load Case 1

51. Load Case 1 is a normal operating condition in which the gate leaves are in the mitered position and subjected to both upper and lower pools (Figure 16). The Corps permits the use of 10 ft of head for girders and 6 ft of head for skin plate to act as minimum equivalent impact loads. Ranges of head are suggested (US Army Corps of Engineers, 1984). The equivalent boat impact load represents a minimum load to which the girders and skin plate are subjected (Figure 17). Hence, it affects only the design of the girders and skin plate in the upper part of the gate. Of course, impact damage on the upper portion of the gate does not imply that the lower portion of the gate is safe, particularly for vertically framed gates.

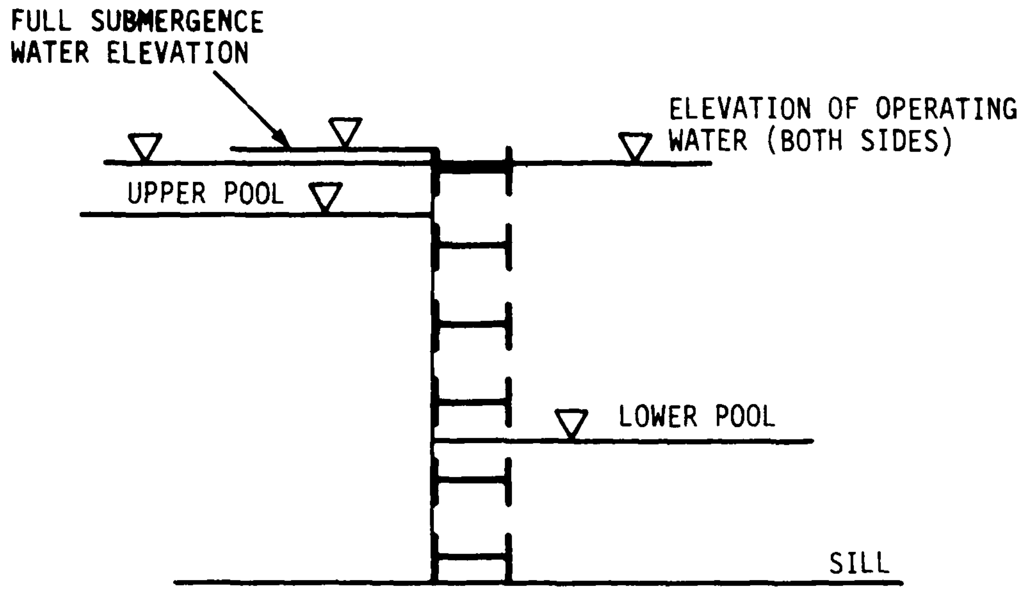


Figure 16. Water elevations

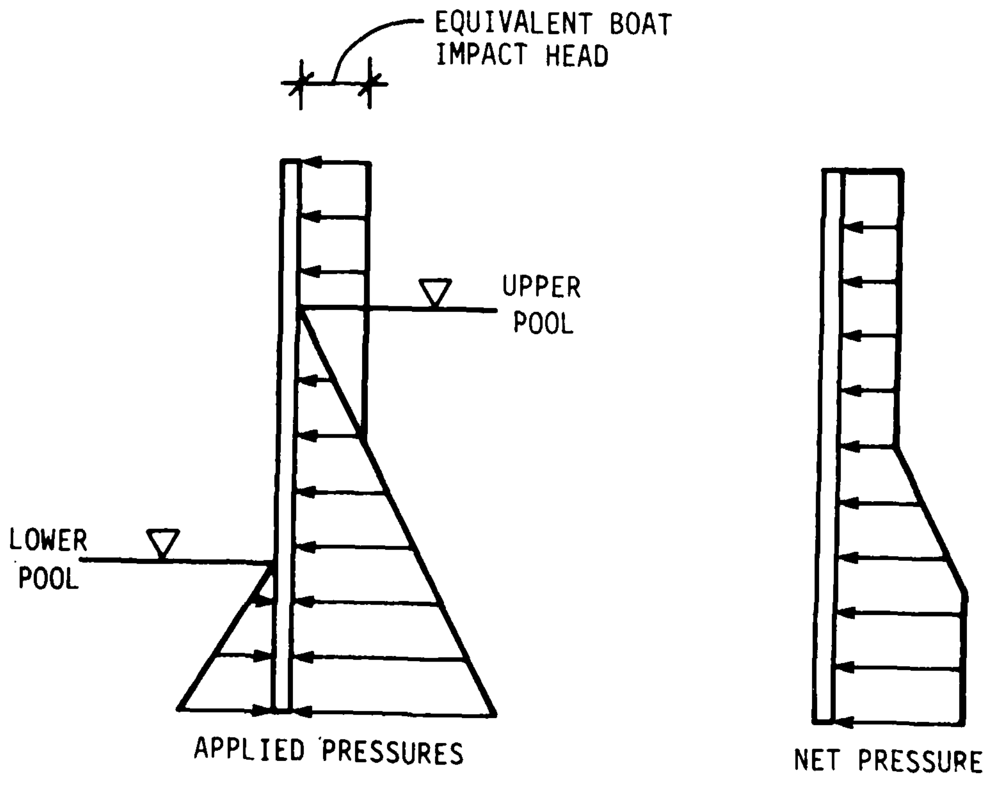


Figure 17. Load case 1

52. Since Load Case 1 is a normal operating condition, the allowable stresses specified in the design manual (US Army Corps of Engineers, 1963) are applicable. The design factor of safety, FS_d, is 2.0.

Load Case 2

53. Load Case 2 consists of the gate leaves in the mitered position with water pressure due to the full upper pool only. This is the dewatered condition (Figure 16).

54. Load Case 2 is an abnormal condition so that a 33 percent increase in the allowable stresses is permitted. The design factor of safety, FS_d, is 1.5.

Load Case 3

55. Load Case 3 consists of dead load (ice and mud) and the water drag when the gate is opening or closing (Figure 16). Load Case 3 does not include static water head.

56. Load Case 3 is an unmitered operating condition that permits the normal allowable stresses. The design factor of safety, FS_d, is 2.0.

Load Case 4

57. Load Case 4 is an unmitered operating condition consisting of the gate weight, live load on the walkway and bridgeway, dead load of ice and mud, and the temporal head (Figure 16). CMINV defaults to 1.25 ft head to represent the temporal load (pulse load or wave resulting from overfill or overemptying).

58. Load Case 4 has no static head and allows a 33 percent increase in the allowable stress. The design factor of safety, FS_d, is 1.5.

Load Case 5

59. Load Case 5, unmitered obstruction, usually controls the design of the strut and pintle. The structural analysis in this project has been limited to three components: girders, skin plate, and intercostals. Load Case 5 does not stress these components and has been omitted.

Load Case 6

60. Load Case 6 consists of Load Case 1 (without boat impact) plus the earthquake condition, which is represented by a constant gate acceleration factor (default equals 0.05 in CMINV).

61. Load Case 6 is the mitered earthquake condition resulting in a 33 percent increase in the allowable stress. The design factor of safety, FS_d, is 1.5.

Component Condition Index for Each Load Case

62. The minimum factor of safety for each of the three components for each load case is determined. It is related directly to the structural condition index by using the condition index zones in Table 2. If the factor

of safety is equal to the design value, the condition index is 100. If the factor of safety falls below one, a Zone 3 (condition index less than 40) is indicated. Figure 18 illustrates the two straight lines that are used to relate the factor of safety and the structural condition index.

$$CI = \begin{cases} 40 \cdot FS & FS < 1 \\ 40 + 60\left(\dfrac{FS - 1}{FS_d - 1}\right) & FS > 1 \end{cases} \qquad \text{[Eq 3.1]}$$

where FS_d is the design factor of safety.

<u>Girders</u>

63. The main girders of horizontally framed gates in the full mitered position of Figure 19 form a series of three hinged arches symmetrical about the centerline of the lock chamber. The forces and reactions acting on one gate leaf, along with the corresponding moment diagram, are shown schematically in Figure 20. The determination of the internal forces and moments within the girders is adequately described in "Lock Gates and Operating Equipment" (US Army Corps of Engineers, 1984).

64. The girder design procedure states that an effective girder section includes an effective width of skin plate, b′, acting as a cover plate. The Corps follows American Institute of Steel Construction (AISC, Section 1.9.1.2), which suggests that

$$b' = \frac{95}{\sqrt{F_y}}\, t \qquad \text{[Eq 3.2]}$$

where t is the plate thickness and F_y is the yield stress in kips/sq in.

65. A telephone conversation with one of the program authors has revealed that the investigation module, CMINV, differs somewhat from the theory given in the Corps manual for the effective webs of girders. CMINV follows AISC, Section 1.9.2.2, which suggests that an effective web depth is

$$d' = \left|\frac{253}{\sqrt{F_y}}(n + 1)\right| t_w + n\, t_s \qquad \text{[Eq 3.3]}$$

where: n = number of longitudinal web stiffeners
t_w = thickness of web
t_s = thickness of longitudinal stiffener

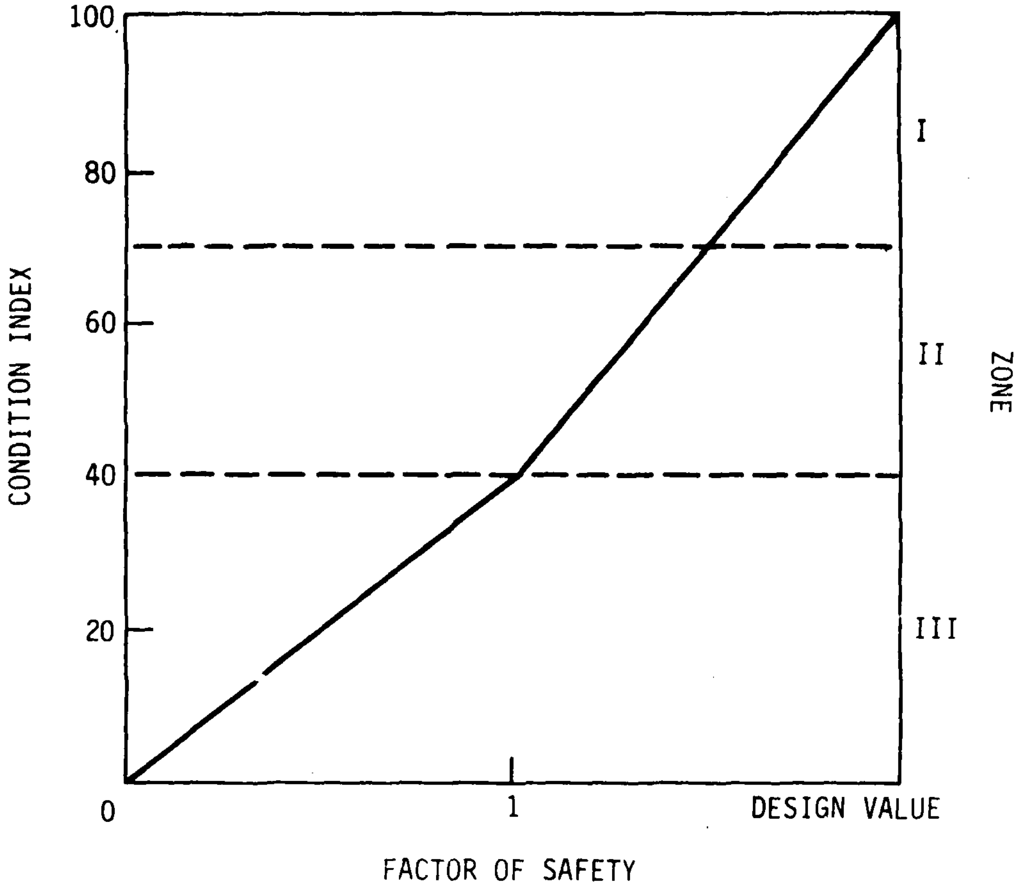


Figure 18. Relationship between factor of safety and structural condition index

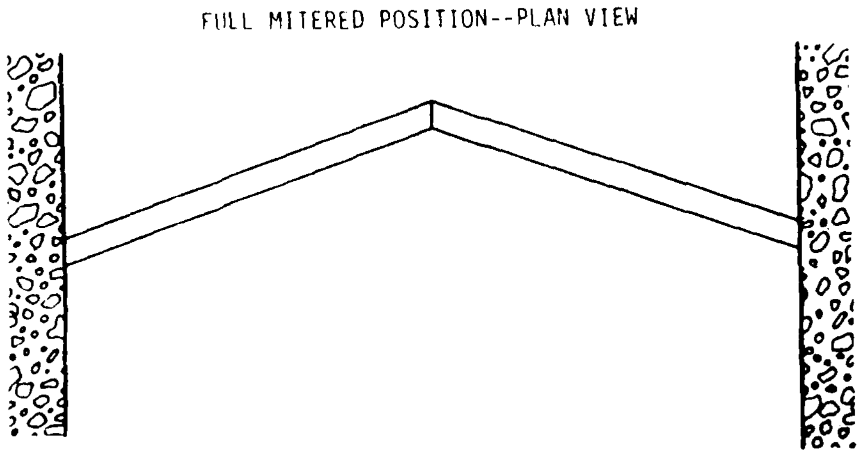
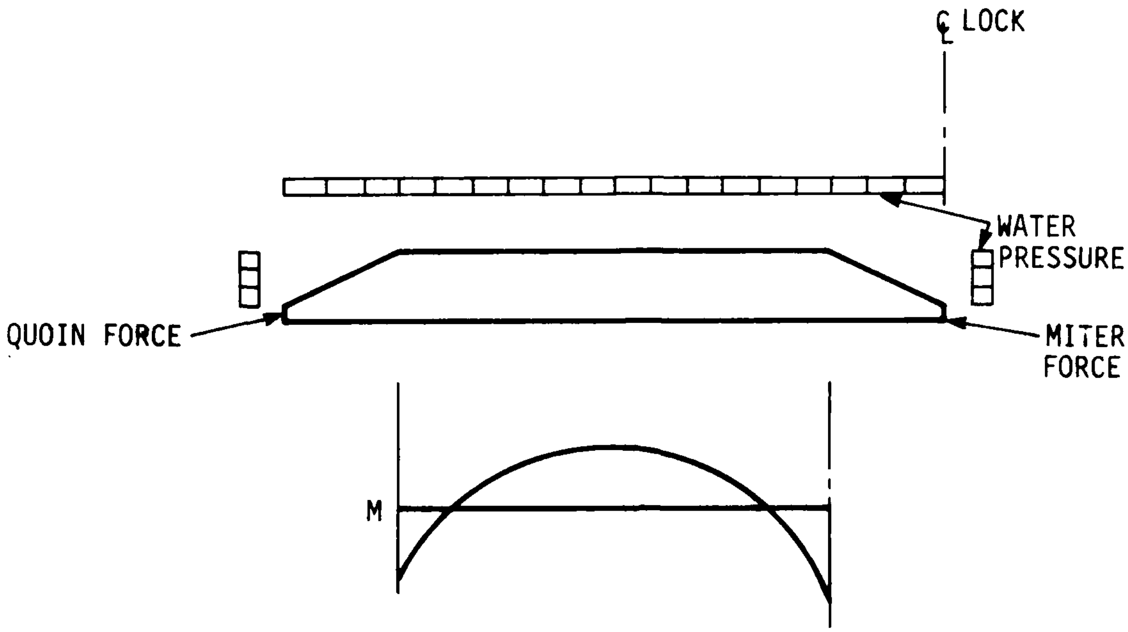


Figure 19. Three-hinged arch



Figue 20. Forces and reactions on miter lock gate

If the actual web area is greater than the effective web area, the effective area is used; otherwise, the actual web area is used. This is a conservative assumption.

66. When a stress analysis is performed, the calculated bending and axial stresses are compared to the allowable stress. The allowable values of axial and bending stress are determined by "Working Stresses for Structural Design" (US Army Corps of Engineers, 1963) or current AISC specifications. The Corps reduces the AISC allowable stresses by a factor of 0.83. The girder effective length for buckling is taken as the distance between end diaphragms, and the radius of gyration is taken around the major axis. As a check for weak axis buckling, the girder effective length is taken as the distance between intermediate diaphragms with a minor axis radius of gyration. The bending factor (BF) is defined as the ratio of actual stress to the allowable stress. For girders, the bending factor, BF, is

67. If $f_a/F_a \leq 0.15$

$$BF = \frac{f_a}{F_a} + \frac{f_b}{F_b} \qquad \text{[Eq 3.4]}$$

68. If $f_a/F_a > 0.15$

$$BF = Maximum \begin{cases} \dfrac{f_a}{F_a} + \dfrac{C_m f_b}{\left(1 - \dfrac{f_a}{F'_e}\right) F_b} \\ \\ \dfrac{f_a}{0.5 F_y} + \dfrac{f_b}{F_b} \end{cases} \qquad \text{[Eq 3.5]}$$

where: f_a = working axial stress

F_a = allowable axial stress (US Army Corps of Engineers, 1963)

f_b = working bending stress

F_b = allowable bending stress (US Army Corps of Engineers, 1963)

F'_e = Euler stress divided by a factor of safety (US Army Corps of Engineers, 1963)

C_m = 0.85

For design, the BF must be less than 1.

69. For each load case i described above:

a. The stress investigation module, CMINV, calculates the bending factors, BF_j, according to Equation 3.4 or Equation 3.5 for up to ten locations along length of girder, $_j$. The number of locations depends on the number of changes in the cross-sectional properties. For example, CMINV calculates the stresses at all changes in cross section, at the center, and at the ends.

b. A computer program, which interfaces with the CMINV output file, calculates the safety factors for each girder, FS_j, as the least factor of safety for all ten locations, or

$$FS_j = \frac{FS_d}{Maximum\,(BF_j)} \qquad \text{[Eq 3.6]}$$

and the condition index, CI_{Gj}, from Equation 3.1.

c. The program calculates the overall condition index for all girders for the load case i, CI_{Gi}, as the minimum of all girder condition indexes,

$$CI_{Gi} = Minimum\,(CI_{Gj}\ for\ all\ girders) \qquad \text{[Eq 3.7]}$$

70. The structural analysis module, CMINV, incorporates current AISC allowable steel stress specifications, current Corps design specifications, and effective web depth criteria into the girder stress investigation. Current analysis and former design techniques recognize the critical section location to be near the end diaphragm. However, several analysis parameters have evolved over time, for example, effective cross-sectional area and beam column interaction equations.

71. The girder cross-sectional area determination may be different from the original design in several ways. Some early design considerations did not recognize the effective web depth criteria given by Equation 3.3. On many gates analyzed by CMINV, the girder effective web depth alone reduced the actual cross-sectional area by as much as 30 percent. This is a conservative analysis technique. Also, the effective skin plate width is calculated by current AISC specifications of plates under compression (Equation 3.2). Early design techniques considered only the skin plate covering the flange to be effective; this was a much more conservative design approximation. In addition, CMINV considers longitudinal stiffeners as part of the cross section. Many designers omitted the longitudinal stiffener from the cross section.

72. The current AISC beam column interaction equations also differ from original design interaction equations. This is because of the constant evolution of the AISC code. Current code uses a column curvature coefficient and an amplification factor. This may or may not be conservative depending on the ratio of f_a/F'_e in Equation 3.5.

73. The combination of the different analysis parameters and methods makes it difficult to compare the CMINV results to the original design calculations. Cherng et al. (1983) concluded that the AISC beam-column formulas currently used to design miter lock gates serve as an excellent approximation if girder failure is governed by compressive stress. In any event, a low girder condition index indicates overstress according to current criteria. (Some girders analyzed by the authors with CMINV showed overstress whereas the designers apparently experienced no overstress when using the criteria in effect at the time.) This should flag the need for further investigation to determine the nature and extent of the problem.

Skin plate

74. The skin plate is located on the upstream side of most horizontally framed miter lock gates and is designed for plate action. For the structural analysis, the edges of the panels are assumed to be fixed at the centerline of the vertical intercostals and at the edges of the horizontal girder flanges (not greater than 6 in. from web center line). Plate theory is used to determine the stress in the skin plate (US Army Corps of Engineers, 1984).

75. The Huber-Mises yield criteria, which combines the two perpendicular stresses in the plate, f_x and f_y, into an effective stress, f, at a particular point is used to evaluate the combined stress.

$$f^2 = f_x^2 + f_y^2 - f_x f_y \qquad \text{[Eq 3.8]}$$

The effective skin plate stress is determined at two locations: (1) at the intercostal, where f_x is the plate analysis stress at the fixed edge, and f_y is the intercostal compressive bending stress from the following section, and (2) at the girder, where f_x is the girder compressive bending stress plus axial stress from the previous section and f_y is the plate analysis stress. For design, the effective stress, f, must be less than 0.75 F_y.

76. For each load case i described above:

a. The stress investigation module, CMINV, calculates the biaxial skin plate stress, f, according to Equation 3.8 for two locations per panel.

b. A computer program interfaces with the CMINV output file and calculates the bending factor, BF_j, for each panel, j, by dividing the effective stress f by the allowable biaxial stress. The program then calculates the safety factor for each panel, FS_j, as the least factor of safety for the two locations according to Equation 3.6 and the condition index, CI_{Sj} from Equation 3.1.

c. The program calculates the overall condition index for all skin plate panels for the load case i, CI_{Si}, according to

$$CI_{Si} = Minimum\,(CI_{Sj}\ for\ all\ skin\ panels) \qquad \text{[Eq 3.9]}$$

Intercostals

77. Intercostals provide stiffness to the skin plate between vertical diaphragms. An effective width of the skin plate is assumed to act with an intercostal (Equation 3.2). Intercostals are modeled as beams simply supported at the girder centerline with the average water pressure at the center of the panel acting on the contributory area as shown in Figure 21. CMINV also calculates a fixed end stress to be used for the end weld analysis. The critical intercostal stress is located at the midspan of the intercostal.

78. For each load case i described above:

a. The stress investigation module, CMINV, calculates the critical midspan intercostal stress for each panel j.

b. A computer program interfaces with the CMINV output file and calculates the bending factor, BF_j, safety factor, FS_j, and condition index, CI_{Ij}, following the same procedure as in the skin plate analysis.

c. The program calculates the overall condition index for all intercostals for the load case i, CI_{Ii}, according to

$$CI_{Ii} = Minimum\,(CI_{Ij}\ for\ all\ intercostals)$$ [Eq 3.10]

Leaf condition index for all load cases

79. The structural condition index for an entire leaf for each individual load case, CI_i, is the minimum condition index of the three component condition indexes, Equations 3.7, 3.9, and 3.10. Thus, for each load case i

$$CI_i = Minimum\,(CI_{Gi}, CI_{Si}, CI_{Ii})$$ [Eq 3.11]

The final leaf structural condition index for all load cases is calculated by taking the minimum of the condition indexes for each load case,

$$CI = Minimum\,(CI_1, CI_2, CI_3, CI_4, CI_6)$$ [Eq 3.12]

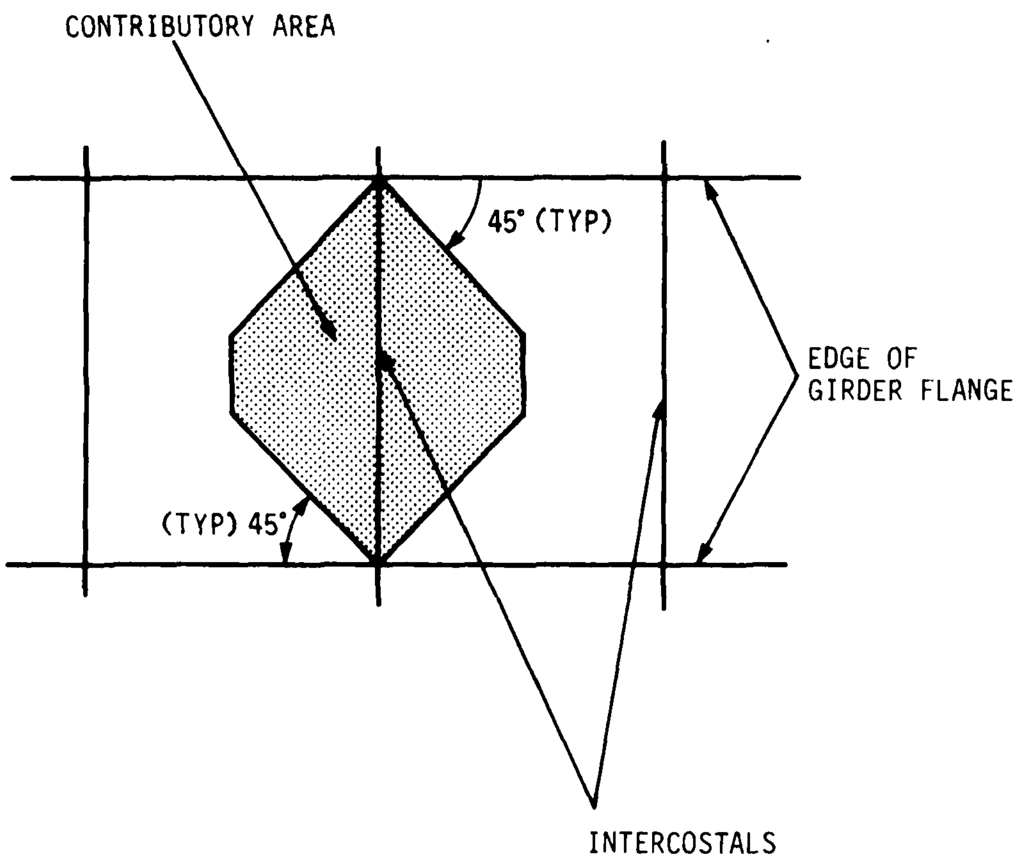


Figure 21. Contributory area for intercoastal

Corrosion Modified Structural Condition Index

80. Corrosion is the loss of steel due to interaction with its environment. The Corps recognizes this material loss and adds 1/16 of an inch to the design thicknesses of the structural components for lock gates. Corroded structural components reduce the safety or structural soundness of a miter lock gate. If a structural component has a low structural condition index, corrosion introduces an additional risk. The material loss from corrosion on a gate is seldom uniform. To account for corrosion losses accurately, locations with reduced thicknesses would have to be carefully mapped during the inspection. A sophisticated analysis technique that allowed localized thickness reductions would follow. A less tedious and more conservative technique is to apply a corrosion factor, representing the worst corrosion level for a component, to the structural condition index of the same component.

$$\textit{corrosion-modified structural CI} = (\textit{structural CI})\ (\textit{corrosion CI}) \qquad \text{[Eq 3.13]}$$

The corrosion condition index is the functional condition index (Distress Code (10) in Part IV) expressed as a fraction for each specific component (girder, skin, and intercostal). The structural condition index is defined earlier for the girders (Equation 3.7), skin (Equation 3.9), and intercostals (Equation 3.10). The corrosion-modified structural condition index in Equation 3.13 is not intended to be a sophisticated correction that reflects all the aspects of corrosion thickness reduction. Such sophistication is beyond the inspection level and analysis level of this project. The equation does, however, recognize that the safety of a structure is compromised by corrosion. As such, if both a reduced structural condition (low factor of safety) and corrosion condition index (high corrosion) occur, it will be reflected by Equation 3.13. This should raise a flag to an engineer that further investigation may be necessary (Zone 3 condition).

81. The corrosion-modified structural condition index for an entire leaf is found as in the previous section. For each load case, Equation 3.11 is used to find the minimum of each component. The minimum of all load cases is the final corrosion-modified structural condition index, Equation 3.12.

PART IV: FUNCTIONAL CONDITION INDEX

82. The second set of criteria that evolved during this project was much more subjective than the structural evaluation described in the previous chapter. This set of criteria involves "engineering judgment" and depends on the experience of the person making the evaluation. These aspects of the condition index were much more difficult to capture. Experts in this field were interviewed, and discussion continued over a year until a consensus began to develop. Preliminary field visits of engineers with lock and dam personnel were conducted at Mississippi Lock and Dam 14 and 15, Wilson and Fort Louden on the Tennessee River, and at Old Hickory on the Cumberland River. After in-depth discussions, actual field tests were conducted at Lock and Dam 15 and 19 on the Mississippi, Kentucky Dam on the Tennessee, and Barkley Dam on the Cumberland. The opinions expressed at these meetings were blended into a set of "expert opinion" rules that are embedded in the evaluation that constitutes the functional condition index. The rules have been designed to interpret straightforward visual observation data in much the same manner that a seasoned engineer would interpret field observations.

83. The experts took many factors into account as they evaluated the functional condition index. One aspect was the serviceability of the structure, that is, its performance at normal and below-normal service conditions on a day-to-day basis. For example, if a miter lock gate is leaking excessively, it is not performing at its intended level of service. Extreme leaks would prevent operation of the lock. Excessive gudgeon pin wear, for instance, will eventually prevent gate operation. The appearance of the gate in its particular location is a factor. Operational noises can indicate problems.

84. Probably a more important factor in the functional condition index is, for lack of a better term, subjective safety. Subjective safety refers to the idea that an engineer, using his or her judgment, may decide that a safety problem is likely. A single observation or series of inspection observations may indicate that potential for a problem exists, or that a safety problem is developing and may soon become critical. These types of observations are difficult to quantify. They cannot, for example, be incorporated into a simple structural analysis, such as those described in Part III. Only a visual indication of the problem is present.

85. As another example, excessive movement of the anchorage embedment may indicate a potential safety problem. The embedded anchorage may have corroded and be approaching a failure condition. The only visual observation may be movement at the steel and concrete interface. Only a more detailed inspection, which may require concrete removal, will reveal the true cause. However, for the purposes of this study, it is certainly appropriate to reduce

the condition index of the gate because of the potential safety problem. Cracks, dents, leaks, downstream movement of the gate during filling, and gaps between the bearing blocks may also indicate safety problems.

86. A series of critical measurements are made on each gate to quantify the functional condition index. Experts were asked to interpret these measurements in light of the serviceability and safety of the gate and assign limiting values to the measurements. Specifically, a series of distresses was identified. Each distress is quantified by a measurement, X. For example, anchorage movement is a distress quantified by three quantities, one of which is the relative motion between the steel and the concrete at their interface. Typically, each distress could either be a problem in itself or an indication of a problem. For example, corrosion distress is itself a problem. Anchorage movement is a problem in itself if it is sufficiently large to impede gate operation, or it could be an indication of a safety problem, as discussed in the previous paragraph.

87. The functional condition index is quantified by

$$Functional\,CI = 100(0.4)^{X/X_{max}} \qquad \text{[Eq 4.1]}$$

where X_{max} is some limiting value of X. Referring to the previous description of action zones (Table 2), X_{max} is defined as the point at which the functional condition index is 40, that is, the dividing point between Zones 2 and 3. Figure 22 illustrates the equation and zones from Table 2. If X is zero, that is, no distress, the condition index is 100. Note that the functional condition index never quite reaches zero. Following the discussion in the paragraphs above, X_{max} for each distress was selected by experts to be the point at which the gate requires immediate repair or, at a minimum, mandates a more detailed inspection and condition index evaluation. In other words, it is a potentially hazardous situation. The experts made the judgment for X_{max} based on serviceability or subjective safety considerations. The mix and weight of serviceability versus safety are incorporated into the experts' judgment. Tables of X_{max} are given for several distresses.

Distress Descriptions and X_{max}

88. If a miter lock gate structure is designed and constructed properly, it has an initial condition index of 100. As time passes and the structure is exposed to varying environmental and operational situations, its condition will deteriorate. The condition index will degrade as various distresses are incurred. A total of ten distresses have been identified for categorization in this project. Each is described briefly in Table 3, and each can detract from the safety and serviceability of miter lock gates.

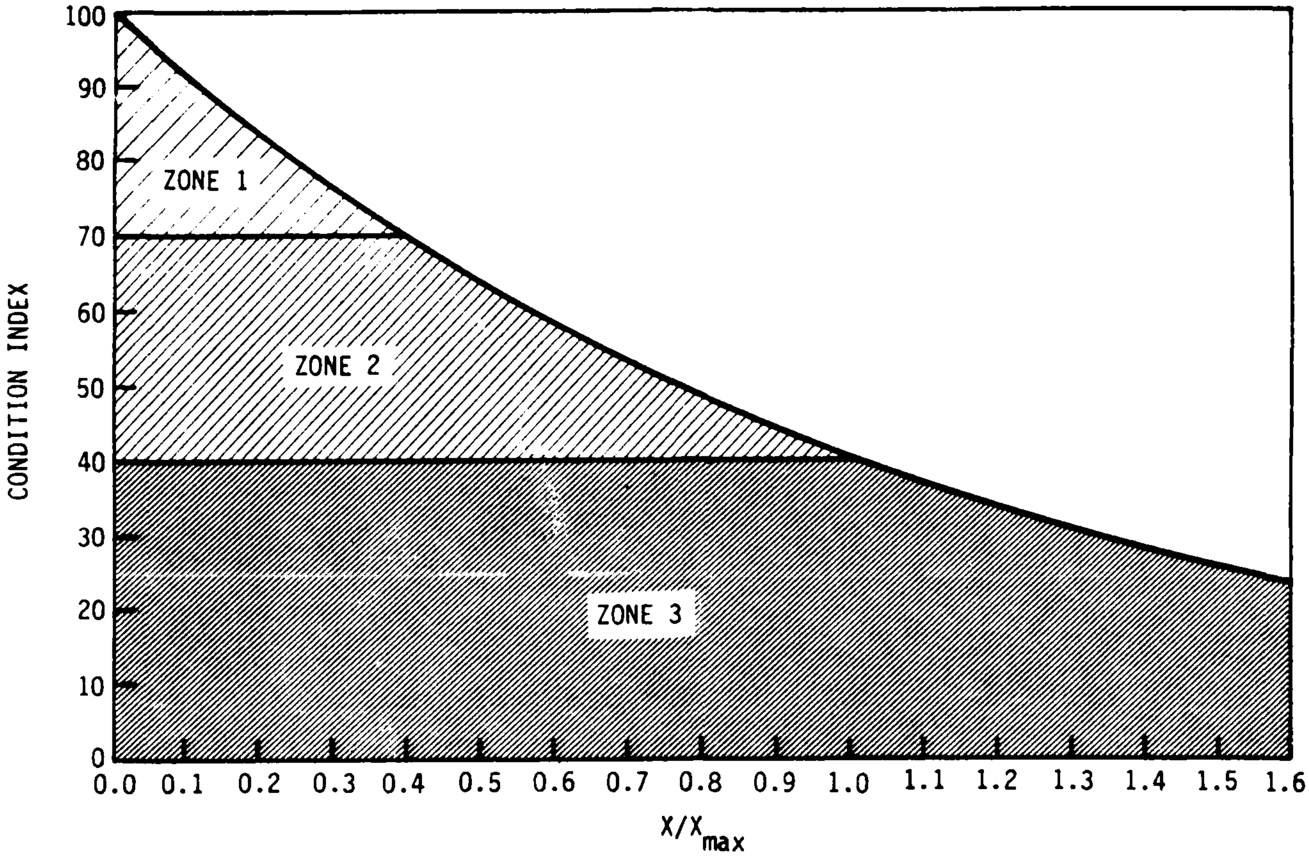


Figure 22. Functional condition index related to X/X_{max}

89. The functional condition index for each distress depends on the ratio of a field measurement X to some limit, X_{max}, as in Equation 4.1. In the following sections, the definition, measurement of X, and X_{max} values for each distress will be described. Values are presented here for consideration by the users of this work.

90. Potential causes of each distress are also listed and discussed. These causes are the problems that must be addressed in the maintenance and repair of the gate. The diagnosis of causes for each distress is a complex issue. Many times, a distress may have several possible causes. Often, a combination of distresses must be present before a certain cause can be identified.

Distress Code (1): Top Anchorage Movement

Definition and causes

91. Anchorage movement is a horizontal, translational displacement of the components that make up the top anchorage system. This movement is in addition to the normal rotation that occurs at the gudgeon pin as the gates

Table 3

Distresses in Miter Lock Gates

Distress Code	Distress	Brief Description
1	Top anchorage movement	Motion of the upper anchorage system during gate operation
2	Elevation change	Vertical displacement of the gate during operation
3	Miter offset	Misalignment of the bearing blocks at the miter point
4	Bearing gaps	Gaps between the bearing blocks at the quoin and miter
5	Downstream movement	Downstream displacement of the miter point as the head is applied
6	Cracks	Breaks in the structural steel components
7	Leaks/boils	Water passing through or around the gate
8	Dents	Disfiguration of the steel components
9	Noise/Vibration	Abnormal noise, vibration, or jumping during gate operation
10	Corrosion	Loss of steel due to interaction with the environment

open and close. Typically, each gate leaf has two anchorage arms, one parallel and one approximately perpendicular to the lock chamber. Movement can occur during opening or closing of the gates and during filling or emptying of the lock chamber. Anchorage movement can be caused by several factors at three locations on each anchor arm (Figure 10).

a. Location 1: Interface of embedded steel with concrete
   - Corrosion of steel within embedment
   - Failure of concrete at embedment
   - Movement of steel within concrete

b. Location 2: Embedded steel to eyebar connection
   - Wedge pin wear
   - Linkage pin or bolt wear

c. Location 3: Eyebar to gate leaf connection
   - Gudgeon pin wear
   - Gudgeon pin bushing wear

The top anchorage system is the only mechanism that connects the top of the lock gate to the lock wall. Hence, the presence of anchorage movement may indicate a significant structural problem, or it could eventually introduce structural problems into other gate components.

Measurement and limits

92. Measurement of the anchorage dimensions will be made at the three locations on each anchor bar (parallel and perpendicular) as illustrated in Figure 10. At Location 2, some anchorage configurations have an additional linkage pin. The measurement of movement at Location 2 will be made across both pin connections. Dimensions will be recorded on the inspection form when the gate leaves are in four positions: recessed (fully open), near mitered, mitered with 1-ft head, and mitered with full head (fully closed). The maximum motion that occurs at Location 1, X_1, is found by subtracting the smallest of the measurements at the four gate positions from the largest. Measurements at locations 2 and 3 are manipulated similarly. Although the position at which the maximum motion occurs is not explicitly contained in the condition index, an experienced engineer may wish to know it to help diagnose the particular cause. The presence of any concrete cracking or spalling in the vicinity of the embedded anchorage at Location 1 is also recorded.

93. A displacement of 0.03 in. has been selected as the limiting motion at Location 1 for all gate sizes.

$$X_{max1} = 0.03 \text{ in.} \qquad \text{[Eq 4.2]}$$

The experts judged that motion greater than this could indicate a significant structural problem. Any spalling or cracking of the concrete in this area will reduce the functional condition index in this area by a factor of 0.85.

94. Location 2 is often a pin connection or a wedge pin connection. The linkage bar usually includes a length adjustment device such as a turnbuckle or wedge plates. The limiting X_{max2} at this location depends on the leaf height, which is critical for the operation of high gates. A limiting value of 0.50 in. was chosen for low gates (width divided by height equal to 2) and 0.125 in. for high gates (width/height equal to 1/2). For other heights, a linear equation that fits these two cases is used:

$$X_{max2} = 0.25 \text{ (width/height)(in.)} \qquad \text{[Eq 4.3]}$$

95. Location 3 is the relative movement of the gudgeon pin with respect to the linkage arm. The maximum displacement at this location was again judged to depend on leaf height. The linear equation

$$X_{max3} = 0.18 \text{ (width/height)(in.)} \qquad \text{[Eq 4.4]}$$

gives a value of 0.36 in. for low gates (width and height equal to 2) and 0.09 in. for high gates (width/height equal to 1/2).

96. The functional condition index for an individual anchor arm is taken as the minimum of the condition indexes of its components:

$$\mathbf{CI = Minimum\ (CI_1,\ CI_2,\ CI_3)} \qquad \text{[Eq 4.5]}$$

The functional condition index for the anchorage movement distress for an individual leaf is the minimum of the condition index for the perpendicular or parallel anchor bars.

Example

97. From measurements at the four leaf positions, a miter lock gate leaf 62 ft wide and 100 ft tall has the following maximum movements in the perpendicular anchor arm:

$$X_1 = 0.004\ in.$$

$$X_2 = 0.02\ in.$$

$$X_3 = 0.04\ in.$$

The concrete around the embedded anchorage (Location 1) is spalled and cracked. From Equations 4.3 and 4.4

$$X_{max2} = 0.25(62/100)) = 0.16\ in.$$

$$X_{max3} = 0.18(62/100) = 0.11\ in.$$

The functional condition indexes for the perpendicular anchor arm are:

$$CI_1 = [100(0.4)^{0.004/0.03}]0.85 = 75$$

$$CI_2 = 100(0.4)^{0.02/0.16} = 89$$

$$CI_3 = 100(0.4)^{0.04/0.11} = 72$$

where the 0.85 factor has been used in CI_1 because the concrete is cracked. By Equation 4.5, the functional condition index for the perpendicular anchor arm is:

$$\mathbf{CI_{perp} = Minimum\ (75,\ 89,\ 72) = 72}$$

This puts the CI in very good condition, namely, the function is not impaired. To continue, the functional condition index for the parallel anchor arm for this example could be:

$$\mathbf{CI_{para} = 82}$$

The functional condition index for the top anchorage movement for this leaf is the minimum of the perpendicular and parallel condition indexes,

$$\mathbf{CI = Minimum\ (72,\ 82) = 72}$$

If the concrete had not been cracked near the perpendicular arm, $CI_{\parallel}$ would be 88 and CI_{perp} would still be 72, which would still control the functional condition index for the top anchorage movement distress and thus give it a very good rating.

Distress Code (2): Elevation Change

Definition and causes

98. The elevation change distress represents vertical displacement of the gate leaves as they are brought from the recessed position to a mitered, full-head position. Elevation change can be caused by several factors.

- Quoin bearing failure, if the elevation change occurs at the quoin as the head is applied.
- Premature quoin contact, if the elevation change occurs at the miter as the gate is brought into miter.
- Blocking out of a floating pintle, if the elevation change occurs at the quoin as the gate is brought to miter and head is applied.

Excessive elevation changes indicate that additional stresses may exist in the gate components, for example, pintle, anchorage, or girders, depending on which of the above causes is identified.

Measurement and limits

99. Measurement of elevation changes will be made at the miter and quoin of each gate leaf with the leaves in four positions:

(1) Recessed.
(2) Near miter.
(3) Mitered with 1-foot head.
(4) Mitered with full head.

From the above causes, the important changes in quoin elevation occur between leaf positions (2) and (4) and between positions (3) and (4). Hence, the X value for the change in quoin elevation is chosen as:

$$X_Q = \text{Maximum}\ [(\text{Elevation}@4 - \text{Elevation}\ @\ 2),\ (\text{Elevation}\ @4 - \text{Elevation}\ @\ 3)] \qquad \text{[Eq 4.6]}$$

The limiting X_{max} value for the change in quoin elevation has been judged to be:

$$X_{maxQ} = 0.05\ \text{ft} \qquad \text{[Eq 4.7]}$$

The limiting X_{max} value for the change in quoin elevation has been judged to be:

$$\mathbf{X_{maxQ} = 0.05\ ft} \qquad \text{[Eq 4.7]}$$

The unit "ft" is used because elevation changes are recorded by a surveying instrument with a level rod graduated in feet. Elevation changes beyond X_{max} are severe and indicate a problem requiring further consideration.

100. The miter elevation change between positions (1) and (3) and positions (2) and (3) is considered important by the experts:

$$\mathbf{X_M = Maximum\ [(Elevation\ @\ 3 - Elevation\ @\ 1),\ (Elevation\ @\ 3 - Elevation\ @\ 2)]} \qquad \text{[Eq 4.8]}$$

The limiting value for the change in miter elevation was judged to be more critical for high leaves. Values of 0.04 ft for high leaves (width/height equal 1/2) and 0.16 ft for low leaves (width/height equal 2) were judged to be appropriate. An equation that gives these values as well as values for intermediate heights is:

$$\mathbf{X_{maxM} = 0.08(width/height)(ft)} \qquad \text{[Eq 4.9]}$$

101. The functional condition index for leaf elevation change is the minimum of the quoin and miter values:

$$\mathbf{CI = Minimum(CI_Q, CI_M)} \qquad \text{[Eq 4.10]}$$

<u>Example</u>

102. The following elevation readings have been recorded in feet for a miter lock gate 70 ft wide and 100 ft tall.

	Position (1)	Position (2)	Position (3)	Position (4)
Miter	3.82	3.81	3.80	3.81
Quoin	3.75	3.74	3.75	3.75

Taken from Equation 4.6, the appropriate X value for the elevation change at the quoin is:

$$\mathbf{X_Q = Maximum[(3.75 - 3.74),(3.75 - 3.75)] = 0.01\ ft}$$

From Equation 4.7,

$$X_{maxQ} = 0.05\ ft$$

From Equation 4.8, the X value for the change in elevation at the miter is:

$$X_M = \text{Maximum } [(3.80-3.82),(3.80-3.81)] = 0.02 \text{ ft}$$

From Equation 4.9,

$$X_{maxM} = 0.056 \text{ FT}$$

The functional condition index for the elevation change at the miter is:

$$CI_M = 100(0.4)^{0.02/0.056} = 72$$

From Equation 4.10, the final CI for elevation change for this leaf is:

$$CI = \text{Minimum } (83,\ 72) = 72$$

Distress Code (3): Miter Offset

Definition and causes

103. The miter offset distress represents gate leaves longitudinally misaligned with respect to each other at the miter blocks as illustrated in Figure 11. In this distress, the bearing blocks at the miter do not meet exactly. Such a condition can introduce eccentricities at the bearing surfaces which, in turn, introduce additional stresses into the structural components of the gate, especially the horizontal girders, as head is applied. Diagonals may also be overstressed. Miter offsets can be caused by several factors:

- Improper diagonal prestress
- Blockage of sill
- Improper closure
- Improper gate alignment
- Deformed gate
- Malfunctioning mitering device.

Safety could be compromised if the condition is severe.

Measurement and limits

104. For a horizontally framed leaf, the miter offset will be measured at the top of the gate, O_1 (Dimension 4, Figure 11) and at the water level, O_2 (Dimension 5, Figure 11) with 1 ft of head (Figure 23). The distance from the walkway will be recorded at each measurement location, Y_1 and Y_2, respectively. The sign convention for miter offset is: right gate farther downstream than the left gate is a positive offset. For the horizontally framed gate, the maximum offset is of concern because it will have the greatest eccentricity. The maximum could, of course, occur at any point along the miter bearing blocks. Since measurements are not made along the entire

length, the miter blocks will be assumed to remain straight. The maximum offset will then occur at the top or at the sill. Since the bearing blocks are assumed to remain straight, the recorded offsets and distances can be used to extrapolate to the offset at the sill,

$$O_S = [O_1(Y_2 - H) + O^2(H - Y_1)]/(Y_2 - Y_1) \qquad \text{[Eq 4.11]}$$

105. Two types of miter offsets will be defined for horizontally framed leaves. The two types usually have different causes. The first type, contact offset, occurs when the miter bearing blocks are nominally parallel and plumb but do not meet properly (Figure 23). Contact offset is measured by the maximum offset distance.

$$X_c = \text{Maximum of absolute values } (Q_1, Q_s) \qquad \text{[Eq 4.12]}$$

If X_c is too large, poor bearing conditions exist and eccentricity is introduced into the leaf girders. The experts judged the limiting case to be

$$X_{maxC} = 2 \text{ in.} \qquad \text{[Eq 4.13]}$$

106. The second type of offset, angular offset, is a measure of the relative angle between the two leaves. In this case, the miter bearing blocks are not parallel. One or both blocks are misaligned with respect to the other in an X-like pattern (Figure 23). Angular offset is expressed as the difference between the sill and top offset:

$$X_A = \text{Absolute value of } (Os - O_1) \qquad \text{[Eq 4.14]}$$

The misalignment represented by this angle is often caused by improper diagonal prestress. The limiting value for angular offset is also selected as:

$$X_{maxA} = 2 \text{ in.} \qquad \text{[Eq 4.15]}$$

but for different reasons than those for contact offset. The presence of flapping diagonals during gate operation will reduce the condition index of the angular offset by a factor of 0.85.

107. The condition index for horizontally framed miter offsets is:

$$CI = \text{Minimum } (CI_C, CI_A) \qquad \text{[Eq 4.16]}$$

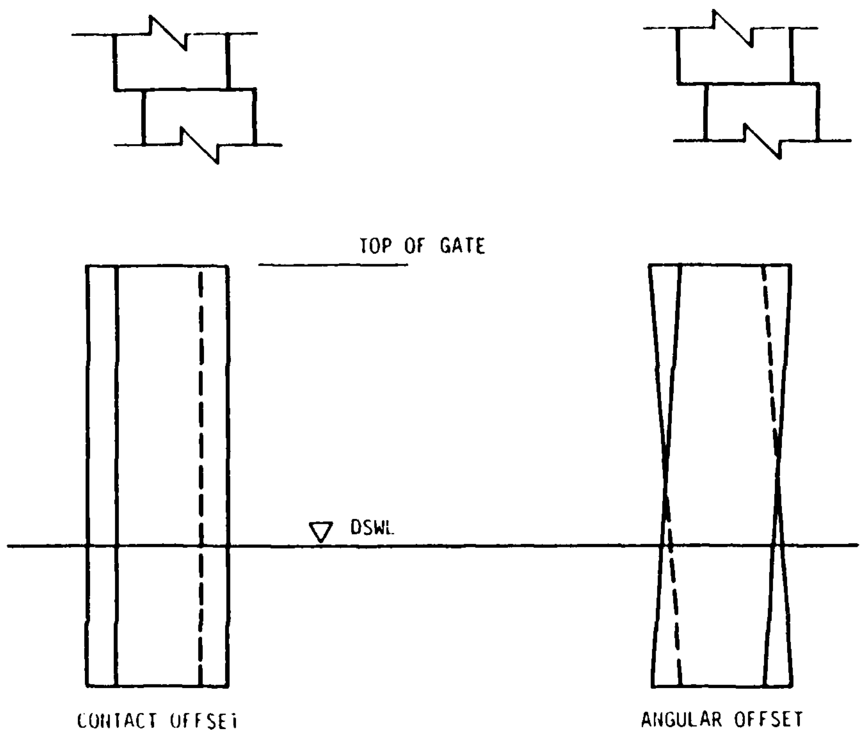


Figure 23. Miter block offsets (contact and angular)

It is the same for both leaves.

108. For a vertically framed gate, only the offset at the top of the miter block, O_1, is measured.

$$X = O_1 \qquad \text{[Eq 4.17]}$$

If X is too large, a poor bearing condition exists and eccentricity is introduced in the top girder as in the horizontally framed case. The limiting value for the vertically framed offset, which is not as critical as for horizontally framed, is:

$$X_{max} = 4 \text{ in.} \qquad \text{[Eq 4.18]}$$

The miter offset condition index applies to both leaves.

<u>Example</u>

109. For a 60-ft-tall horizontally framed miter lock gate, the following miter offsets were recorded. The diagonals did not flap when either leaf was opened and closed.

O_1 = +1 in. $\qquad$ Y_1 = 1 ft

O_2 = +1/8 in. $\qquad$ Y_2 = 26 ft

From Equation 4.11,

$$O_S = \frac{[1(26 - 60) + 1/8(60 - 1)]}{(26 - 1)} = -1.1 \text{ in.}$$

The contact offset is (Equation 4.12):

$$X_c = \textbf{Maximum of absolute value } (1, 1.1) = 1.1 \textbf{ in.}$$

The condition index for the contact offset is:

$$CI_c = 100(0.4)^{1.1/2} = 60$$

The angular offset between the two leaves is:

$$X_A = \textbf{Absolute value}(-1.1 - (+1)) = 2.1 \textbf{ in.}$$

The condition index for angular offset is:

$$CI_A = 100(0.4)^{2.1/2} = 38$$

The condition index for all miter offsets is:

$$CI = \textbf{Minimum}(50,38) = 38$$

which is a poor rating, a Zone 3 condition.

Distress Code (4): Bearing Gaps

Definition and causes

110. The bearing gap distress represents an opening or separation of the bearing blocks at the miter, quoin, or both (Figure 12). Vertically framed gates can have a gap at the top girder only, whereas on horizontally framed gates the bearing gaps can run anywhere along the continuous length of the bearing blocks. Bearing gaps introduce additional stresses into the gate leaves because the gaps are forced closed as head is applied. Safety can be compromised if the gaps are excessive. Gaps can be caused by several factors:

- Anchorage system wear
- Bearing block wear (quoin or miter)
- Shifting of a floating pintle
- Blockage at the sill
- Improper gate alignment
- Deformed gate
- Improper adjustment of anchorage system
- Improper adjustment of gate seals (on vertical frame gates).

Measurement and limits

111. For a horizontally framed gate, measurements of the miter block gap will be made at the top of the gate, MG_1, and at the water level, MG_2, under a 1-ft head situation (Dimension 7, Figure 12). Since gaps will not be measured

along the entire length, the miter blocks will be assumed to remain straight as for the offset distress. The recorded gaps and the respective vertical locations, Y_1 and Y_2, can be used to extrapolate the bearing gap between miter blocks at the sill, MG_S, by a straight line equation,

$$MG_s = \frac{MG_1(Y_2-H)+MG_2(H-Y_1)}{(Y_2-Y_1)} \qquad \text{[Eq 4.19]}$$

The X_M value for miter block gaps on a horizontally framed gate is the maximum gap.

$$X_M = \text{Maximum } (MG_1,\ MG_s) \qquad \text{[Eq 4.20]}$$

The limiting value for miter block gaps in a horizontal framed gate has been selected as:

$$X_{maxM} = 1/2 \qquad \text{[Eq 4.21]}$$

The presence of a leak at the miter bearing blocks, which follows the rising (emptying) water level and closes as the water level continues to rise (empty), will also be recorded. The presence of this type of leak suggests a bearing gap that is forced closed as head pressure is applied. This level causes concern about stresses induced as the gap is forced closed. Any leaks following the rising (emptying) water level will reduce the functional condition index by a leak factor, LF.

LF = 1 (no leaks at changing water level) [Eq 4.22]
LF = 0.85 (leak present at changing water level)

112. For a horizontally framed gate, measurements of the quoin block gap will also be made at the top of the gate, QG_1, and at the water level, QG_2, under a 1-ft head situation (Dimension 6, Figure 12). If the quoin blocks are assumed to remain straight, the recorded gaps and respective vertical locations, Y_1 and Y_2, can be used to extrapolate the gap between quoin blocks at the sill, QG_S, by a straight line.

$$QG_s = \frac{[QG_1\ (Y_2 - H)\ +\ GQ_2\ (H - Y_1)]}{Y_2 - Y_1)} \qquad \text{[Eq 4.23]}$$

The gap between the quoin blocks at the sill may be affected by the type of pintle. If the pintle is fixed, then the important value is:

$$X_Q = \text{Maximum } (QG_1, QG_S) \qquad \text{[Eq 4.24]}$$

If the pintle is floating, then

$$X_Q = \textbf{Maximum}(QG_1, QG_2) \qquad \text{[Eq 4.25]}$$

The X_{maxQ} value for quoin blocks on a horizontal framed gate has been selected the same as for the miter,

$$X_{maxQ} = 1/2 \text{ in.} \qquad \text{[Eq 4.26]}$$

Any leaks at the quoin that follow the rising (emptying) water level will reduce the condition index of the quoin by the leak factor (Equation 4.22).

113. For a vertically framed gate, measurements of the miter block gap and the quoin block gap will be made at the top girder bearing block, under a 1-ft head situation. Because this is the only bearing contact point between the gate leaves, the measurement could normally be expected to be zero when the 1-ft gate leaves achieve a stable mitered position with head. The exception would probably be leaf blockage by foreign material or improper adjustment of miter seals. The X_M and X_Q values for the miter and quoin block gap on a vertically framed gate are the measurements MG_1 and QG_1, respectively. Leaks at the seals are not a factor. The X_{max} value for bearing block gaps on a vertically framed gate has been selected as:

$$X_{maxM} = X_{maxQ} = 1/2 \text{ in.} \qquad \text{[Eq 4.27]}$$

Gaps in the bearing blocks of vertically framed gates would normally not introduce additional stress into the top girder as the gap is forced closed. However, distortion must occur somewhere within the leaf to permit gap closure.

114. The condition index for all gaps is the minimum of the condition indexes of the miter or quoin bearing gaps.

$$CI = \textbf{Minimum}\ (CI_M, CI_Q) \qquad \text{[Eq 4.28]}$$

<u>Example</u>

115. For a 78-ft tall horizontally framed miter lock gate having a fixed pintle, the following gaps were recorded at the miter and quoin.

$MG_1 = 1/8$ in. $Y_1 = 1.5$ ft
$MG_2 = 3/16$ in. $Y_2 = 40$ ft
$QG_1 = 1/4$ in. $Y_1 = 2$ ft
$QC_2 = 3/8$ in. $Y_2 = 42.5$ ft

By Equation 4.19

$$MG_S = \frac{[1/8(40 - 78) + 3/16\ (78 - 1.5)}{(40-1.5)} = 0.25 \text{ in.}$$

By Equation 4.20

$$X_M = \text{Maximum } (0.25,\ 1/8) = 0.25 \text{ in.}$$

For the quoin, by Equation 4.23

$$QG_S = \frac{[1/4\ (42.5 -78) + 3/8\ (78-2)}{(42.5\ -2)} = 0.48 \text{ in.}$$

and Equation 4.24

$$X_Q = \text{Maximum } (0.25, 0.48) = 0.48 \text{ in.}$$

A leak followed the rising water level only at the quoin. The condition index for the miter gap is (by Equation 4.1):

$$CI_M = 100(0.4)^{0.25/0.5} = 63$$

The condition index for the quoin gap is

$$CI = [100(0.4)^{0.48/0.5}]0.85 = 35$$

The condition index for all gaps is

$$CI = \text{Minimum } (63, 35) = 35$$

If the same leak pattern would have occurred at the miter instead of the quoin, the condition index for the miter gap would have been 54 and the condition index for the quoin gap would have been 41, resulting in a condition index of 41 for all gaps.

Distress Code (5): Downstream Movement

Definition and causes

116. Downstream movement is a displacement of the miter point in the downstream direction as head is applied. This displacement occurs between the 1-ft head and full-head positions. Downstream movement can be caused by several factors:

- Shifting of floating pintle
- Failed pintle anchorage (fixed pintle)
- Bearing block wear (quoin or miter blocks)
- Sill wear (vertically framed gate)

- Blockage at sill
- Improper gate alignment at miter.

Excessive downstream movement can indicate that a structural failure has occurred or that additional stresses have been introduced.

Measurement and limits

117. Measurements of the horizontal movement of the miter point will be taken at two locations on the downstream face of the miter point in the mitered position. Longitudinal location will be measured near the top of the gate and as close to the downstream water surface as possible. A downstream displacement is considered positive. The displacement and distance from the walkway (Y_1 and Y_2, respectively) will be recorded at the 1-ft head and full-head positions. The downstream movements at the two locations, L_1 and L_2, respectively, are found by subtracting the measurements at the 1-ft head and full-head positions (Dimension 8, Figure 12). If the mitered ends of the gates are assumed to remain straight, as before, the recorded displacements can be used to extrapolate the longitudinal movement of the gate at the sill, L_s, by a straight line.

$$L_s = \frac{[L_1 \ (Y_2 - H) + L_2 \ (H - Y_1)]}{Y_2 - Y_1)} \qquad \text{[Eq 4.29]}$$

The controlling measurement is taken as

$$X = L_s \qquad \text{[Eq 4.30]}$$

The limiting displacement at the sill is

$$X_{max} = 4.0 \text{ in.} \qquad \text{[Eq 4.31]}$$

for all types of gates and all heights of gates. The experts' reasoning for the different gates was somewhat different but the numerical values were similar.

Example

118. For a 62-ft-tall miter lock gate, the following net downstream horizontal movements were recorded.

$$L_1 = 1.0 \text{ in.} \qquad Y_1 = 1.1 \text{ ft}$$
$$L_2 = 1.3 \text{ in.} \qquad Y_2 = 45 \text{ ft}$$

By Equation 4.29, the extrapolated net displacement at the sill is:

$$X = \frac{[1.0 \ (45 - 62) + 1.3 \ (62 - 1.1)]}{(45 - 1.1)} = 1.4 \text{ in.}$$

The condition index for the downstream movement is:

$$CI = 100(0.4)^{1.4/4} = 73$$

Distress Code (6): Cracks

Definition and causes

119. Cracks usually represent a narrow opening, break, or discontinuity in the structural steel members. Cracks are caused by fatigue, vibration, brittle fracture, or overstressed structural steel components. Often, barge or vessel impact is responsible. Obviously, cracks have significant structural implications. Cracks can continue to grow if the cause of the overstress still exists or if the remaining steel cross section cannot carry the normal loads.

Measurements and limits

120. The number of occurrences of cracks in the girders (G), skin (S), or intercostals (I) will be recorded on both the upstream and downstream faces of the gate leaf. Size and location of cracks are also recorded but are not used in the calculation of the condition index. It is implicitly assumed that very large cracks do not occur at the time of the inspection. Such cracks would be recognized and repaired immediately because of possible severe consequences. The limiting value for girder cracks is:

$$X_{maxG} = 1 \qquad \text{[Eq 4.32]}$$

One crack in a girder is considered critical. The limiting value for skin plate and intercostal cracks, is:

$$X_{maxS} = 10 \qquad \text{[Eq 4.33]}$$

$$X_{maxI} = 10 \qquad \text{[Eq 4.34]}$$

The skin and intercostals are highly redundant and can tolerate more cracks with less severe consequences. Failure of an entire skin plate panel would be a big problem, but not disastrous. The condition index for all cracks is taken as the minimum of girder, skin, and intercostal values.

$$CI = \text{minimum}\ (CI_G, CI_S, CI_I) \qquad \text{[Eq 4.35]}$$

Example

121. The following numbers of cracks were counted for a miter lock gate leaf.

$$X_G=0$$
$$X_S=3$$
$$X_I=1$$

The condition index for girder cracks is

$$CI_G = 100(0.4)^{0/1} = 100$$

The condition index for skin plate cracks is

$$CI_S = 100(0.4)^{3/10} = 76$$

The condition index for intercostal cracks is

$$CI_I = 100(0.4)^{1/10} = 91$$

The condition index for all cracks is

$$CI = \text{Minimum } (100, 76, 91) = 76$$

Distress Code (7): Leaks and Boils

Definition and causes

122. The leak distress represents water passing through or around the gate leaves. Several kinds of skin and seal leaks or boils can be tolerated because they usually do not present a significant structural problem. For example, leaks along the vertical edges at a vertically framed gate may indicate seal wear or deterioration. Although the leak may be troublesome, it does not necessarily indicate a safety risk. On the other hand, leaks or boils on load bearing surfaces indicate structural problems because such leaks result from incomplete bearing. They would be interpreted similarly to bearing gaps (Distress Code 4). Skin leaks, however, have an interpretation similar to skin cracks. Leaks and boils are caused by several factors:

- Corrosion
- Structural cracks
- Vessel impact
- Bearing block wear
- Shifting of a floating pintle
- Blockage at the sill
- Improper gate alignment
- Improper adjustment at anchorage system

- Quoin bearing material failure
- Seal wear
- Concrete failure behind quoin bearing plate.

Measurement and limits

123. The location and length, L_S (ft), of skin plate leaks are recorded. Point or very short leaks are recorded with a length equal to zero. The X_S value for skin plate leaks is

$$X_s = \text{Sum of } L_s \quad \text{[Eq 4.36]}$$

Point leaks and leaks shorter than 1 ft are added as 1 ft leaks. The X_{maxS} value for skin leaks is

$$X_{maxS} = 15 \text{ ft} \quad \text{[Eq 4.37]}$$

124. The location and total length of quoin block, L_Q, and miter block, L_M, leaks are also recorded. Quoin and miter leaks are visible leaks above the water surface. The X_{QM} (ft) value for quoin and miter leaks is

$$X_{QM} = L_Q + L_M \quad \text{[Eq 4.38]}$$

The entire quoin and miter areas on a horizontally framed gate are load bearing. Leaks through these surfaces indicate incomplete bearing; that is, the structure is not performing as designed. The limiting value is expressed as a fraction of gate height (ft).

$$X_{maxQM} = (height)/10(ft) \quad \text{[Eq 4.39]}$$

The limiting length of leaks on an 80-ft horizontally framed leaf would be 8 ft.

125. The quoin and miter areas of a vertically framed gate are covered by seals. The bearing surface is located only at the top of the miter and quoin. The limiting value is significantly larger than for a horizontally framed gate.

$$X_{maxQM} = (height)/5(ft) \quad \text{[Eq 4.40]}$$

The maximum amount of leaks on a 40-ft vertically framed leaf would then be 8 ft.

126. Boils are leaks that occur under water. The occurrence of boils in the quoin and miter areas and along the sill is recorded. The X value for boils is

$$X_B = \text{Total number of boils} \quad \text{[Eq 4.41]}$$

Only one boil should be permitted on a bearing surface; two could be allowed on sealing surfaces. The corresponding limiting value for both horizontally and vertically framed leaves is

$$X_{maxB} = 3 \qquad \text{[Eq 4.42]}$$

If the leaf vibrates when the chamber is filling, CI_B is multiplied by 0.85.

127. The condition index for all leaks and boils is

$$CI = \text{Minimum}(CI_S, CI_{QM}, CI_B) \qquad \text{[Eq 4.43]}$$

Example

128. A 40-ft-tall, vertically framed gate has the following leak data:

Skin: L_S = 7 ft and 4 point leaks

Quion and Miter: L_Q = 3 ft and L_m = 2 ft

There was a boil at both the miter and quoin. From Equation 4.36

$$X_S = 7 + 4 = 11 \text{ ft}$$

The condition index for skin leaks is

$$CI_S = 100(0.4)^{11/15} = 51$$

From Equation 4.38, the X_{QM} value for bearing leaks is

$$X_{QM} = 3 + 2 = 5 \text{ ft}$$

From Equation 4.40, the X_{maxQM} is

$$X_{maxQM} = 40/5 = 8\text{ft}$$

The condition index for bearing leaks is then

$$CI_{QM} = 100(0.4)^{5/8} = 56$$

Because one boil occurred at both the miter and quoin,

$$X_B = 2$$

From Equation 4.41 the condition index for boils is

$$CI_B = 100(0.4)^{2/3} = 54$$

The condition index for all leaks and boils is

$$CI = \text{Minimum } (51,56,54) = 51$$

Distress Code (8): Dents

Definition and causes

129. Dents represent a disfiguration of the major components of miter lock gate leaves. Dents can be caused by several factors; most often, barge or vessel impact. Dents, particularly in girders, can cause structural distress and possibly a safety problem. A badly deformed girder cannot safely carry its design load.

Measurements and limits

130. The number of dents on the girders, skin, or intercostals will be recorded on both upstream and downstream faces of the gate leaf. Size and location of dents are also recorded but are not used in the calculation of the condition index. The limiting value for the number of girder dents is

$$X_{maxG} = 1 \qquad [Eq\ 4.44]$$

The limiting value for the number of skin plate dents is

$$X_{maxS} = 10 \qquad [Eq\ 4.45]$$

The limiting value for the number of intercostal dents is

$$X_{maxI} = 3 \qquad [Eq\ 4.46]$$

131. As with cracks, the condition index for all dents is the minimum:

$$CI = \text{Minimum } (CI_G, CI_S, CI_1) \qquad [Eq\ 4.47]$$

Example

132. The following dent data were obtained for a miter lock gate leaf.

$$X_G = 0 \quad X_S = 4 \quad X_1 = 1$$

The condition index for girder dents is

$$CI_G = 100(0.4)^{0/1} = 100$$

The condition index for skin dents is

$$CI_S = 100(0.4)^{4/10} = 69$$

The condition index for intercostal dents is

$$CI_I = 100(0.4)^{1/3} = 74$$

The condition index for all dents is

$$CI = \text{Minimum } (100,\ 69,\ 74) = 69$$

Distress Code (9): Noise and Vibration

Definition and causes

133. The noise and vibration distress represents abnormal gate sounds and vibrations during opening and closing of the gate and are caused by several factors:

- Load shift in the anchor bars
- Seizing of pintle
- Poorly lubricated pintle system
- Loss of diagonal prestress
- Obstructions at sills or quoins.

Abnormal noises commonly indicate a problem. Often a noise is difficult to isolate and diagnose, but if it is abnormal, it should not be ignored.

Measurement and limits

134. Noise is recorded when it occurs at a specific location as the gate is opened or closed. The presence of vibration at any point in the gate swing is also recorded. Noises (other than flapping diagonals) occurring between the fully recessed position (0 percent mitered) and 25 percent mitered are not used in determining the condition index. A load shift from tension to compression occurs in the parallel anchorage in this interval. Any excessive anchorage movement will be recorded as a anchorage system distress and is covered under Distress Code 1. The noise from flapping diagonals is accounted for in the miter offsets (Distress Code 3). Noises occurring when the gate is over 90 percent closed are not recorded because several routine or normal noises occur at or near the fully mitered position. Between the 30 and 90

percent mitered positions, any abnormal noise will affect the condition index. The condition indexes for the possible noise and vibration combinations follow.

Noise, Vibration, or Jumping	CI
None	100
Yes for any one of the three	70
Yes for any two	40
Yes for all three	30

Obviously, this distress is more subjective and less quantifiable than the others; however, this should not minimize its importance, because abnormal noises almost always indicate abnormal behavior, which should be investigated.

Example

135. As a miter lock gate leaf was brought into the miter position, it made a popping noise at 75 percent closure. The condition index is

$$CI = 70$$

If the gate would have jumped in addition to the noise, the condition index would have been 40.

Distress Code (10): Corrosion

Definition and causes

136. Corrosion is the loss of the steel material in a miter lock gate leaf due to interaction with its environment. The rate of corrosion depends on the concentration of moisture in contact with the steel. A miter lock gate structure is exposed to different areas of corrosion (Figure 24). While corrosion is usually very evident and easily noticed in the exposed areas, it is often the concealed components, that is, those well below the water surface, that are of most concern for safety reasons. Most light corrosion has little structural significance. However, extensive corrosion can sufficiently reduce the steel cross-sectional area so that stresses are significantly increased. Girder corrosion is more critical than skin corrosion just as girder cracks are more important than skin cracks. Note that the corrosion condition index is also used to calculate the structural condition index (see Part III).

Measurement and limits

137. The effect of corrosion in the atmospheric and splash zones is used to evaluate the corrosion condition index because it is visible there. A distress coefficient for corrosion must take into account that corrosion of a

miter lock gate structure seldom impedes the operation of the structure. However, its safety has been reduced. The effect is a subjective evaluation of safety that is difficult to quantify by measurements or simple testing. One way to evaluate the corrosion of a structure is to set a series of standards, or levels of corrosion, having corresponding numeric distress coefficients. The base for such an evaluation standard would be new steel or clean and painted structural steel with no scale or pitting. Table 4 describes corrosion levels, and the associated photographs in Figure 25 illustrate the various levels of corrosion that are used in the evaluation of the corrosion condition index. The corrosion levels of the girders (G), skin (S), and intercostals (I) will be recorded on both upstream and downstream faces of the gate leaf. The corrosion levels represent the X values.

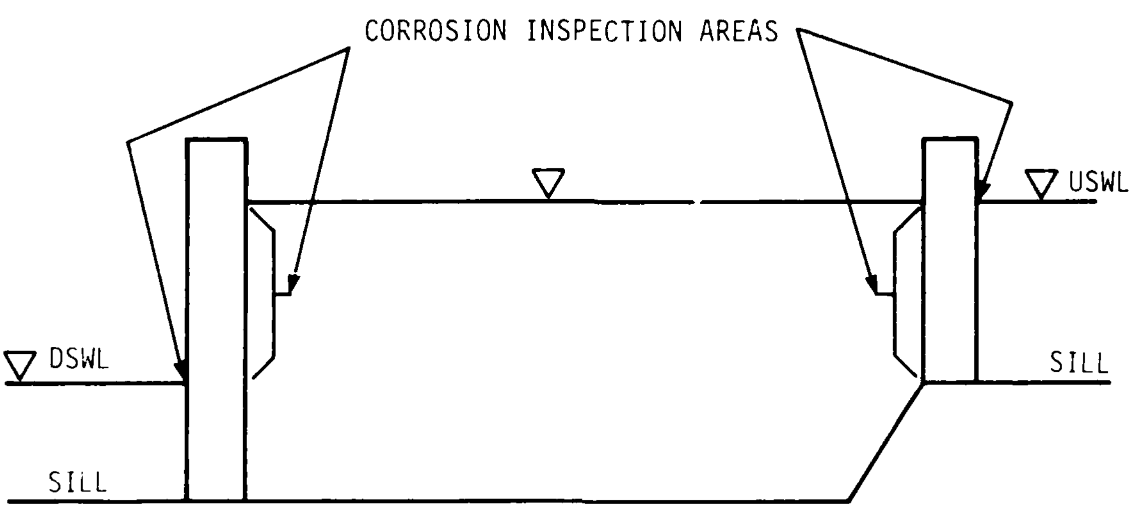
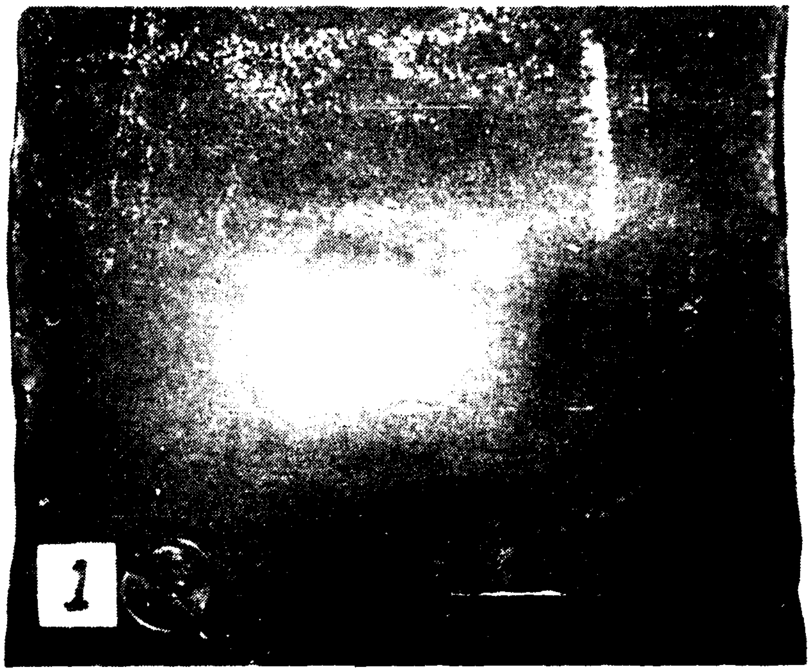


Figure 24. Corrosion inspection areas

Table 4

Levels of Corrosion

Level	Description
0	New condition
1	Minor surface scale and widely scattered small pits
2	Considerable surface scale and moderate pitting
3	Severe pitting in dense pattern, thickness reduction in local areas
4	General uniform thickness reduction
5	[illegible] thickness reduction and general thickness reduction



(b) Level 2: Considerable surface scale and/or moderate pitting

(c) [illegible]

(d) Level 4: Obvious uniform thickness reduction

138. The limiting values for girder corrosion (X_{maxG}), skin corrosion (X_{maxS}), and intercostal corrosion (X_{maxI}), are

$$X_{maxG} = 3 \qquad X_{maxS} = 4 \qquad X_{maxI} = 4 \qquad \text{[Eq 4.48]}$$

As noted above, girder corrosion has more significance than skin corrosion because of the critical structural nature of the girders.

139. The condition index for the girder, skin, and intercostal corrosion will be the minimum of the downstream (D) and the upstream (U) corrosion condition indexes; this is similarly true for the skin and intercostals.

$$CI_G = \text{Minimum}(CI_{DG}, CI_{UG}) \qquad CI_S = \text{Minimum}(DI_{DS}, CI_{US}) \qquad CI_I = \text{Minimum}(CI_{DI}, CI_{UI}) \qquad \text{[Eq 4.49]}$$

The corrosion condition index for a leaf is the minimum,

$$CI = \text{Minimum}(CI_G, CI_S, CI_I) \qquad \text{[Eq 4.50]}$$

Example

140. A miter lock gate leaf has the following corrosion levels recorded for the upstream and downstream surfaces of its major structural components.

Girder:	$X_{DG} = 2$	$X_{UG} = 1$
Skin:	$X_{DS} = 1$	$X_{US} = 2$
Intercostals:	$X_{DI} = 1$	$X_{UI} = 2$

From Equations 4.48 and 4.49, the condition index for girder corrosion is

$$CI_{DG} = 100(0.4)^{2/3} = 54$$
$$CI_{UG} = 100(0.4)^{1/3} = 74$$
$$CI_G = \text{Minimum}(54, 74) = 54$$

The condition index for skin corrosion is

$$CI_{DS} = 100(0.4)^{1/4} = 80$$
$$CI_{US} = 100(0.4)^{2/4} = 63$$
$$CI_S = \text{Minimum}(80, 63) = 63$$

The condition index for intercostal corrosion is

$$CI_{DI} = 100(0.4)^{1/4} = 80$$
$$CI_{UI} = 100(0.4)^{2/4} = 63$$
$$CI_{I} = \text{Minimum } (80,\ 63) = 63$$

The condition index for entire corrosion over the gate leaf is

$$CI = \text{Minimum } (54,\ 63,\ 63) = 54$$

Multiple Distresses

141. When several types of distress occur simultaneously, such as both anchorage movement and offset, the condition indexes are combined into a single value. Weighting factors are introduced to reflect the importance of the various distresses. Hence, let w_i be the weighting factor for the functional condition index for distress i. The weighting factors assign more value to the more significant distresses. Relative initial weights are listed in Table 5. They reflect, to some degree, the opinion of the Corps experts. These factors also represent the opinion of the authors. The table illustrates that anchorage movement is the most important and dents the least important.

142. The normalized weighting factors are defined by

$$W_i = w_i / \Sigma w_i (100) \qquad \text{[Eq 4.51]}$$

Note that

$$\Sigma W_i = 100 \qquad \text{[Eq 4.52]}$$

Values are listed in Table 5 (rounded to add up to 100). The combined functional condition index for all distresses is then given by

$$\text{Functional } CI = W_1 CI_1 + W_2 CI_2 + \ldots \qquad \text{[Eq 4.53]}$$

where the sum is for all ten distresses.

143. During the field testing of a preliminary version of the above rating procedure, it became clear that, as a distress became more severe, its relative importance became larger. To account for this, a variable adjustment factor was introduced to increase the distress weighting factor as its functional condition index approached Zone 3 (0 to 39). The adjustment factor, plotted in Figure 26, has a maximum value of eight; that is, if a distress has a condition index less than 40, its importance increases 8 times.

Table 5

Unadjusted Weighting Factors for Distresses

Distress Code	Distress	W_i	W_i (%)
1	Anchorage movement	11	18
2	Elevation change	9	14
3	Miter offset	5	8
4	Gaps	8	13
5	Downstream movement	7	11
6	Cracks	6	10
7	Leaks and boils	3	5
8	Dents	1	2
9	Noise, jumping, or vibration	7	11
10	Corrosion	5	8

Field Testing

144. The analysis of the performance of the rating rules presented in this part is a study of the calculated functional condition index versus subjective condition index values determined by a group of miter lock gate expert engineers. The expert engineers provided the guidance for establishing and selecting distress rule values and observation ratings of the field test miter lock gates. The miter lock gate experts who participated in the initial rule development were Mr. Jack Sirak and Mr. Eugene Ardine (Ohio River Division), Mr. Richard Atkinson (Rock Island District), Mr. D. Wayne Hickman, and Mr. Lynn Midget (Nashville District).

145. The inspection and rating procedure has been applied in three field tests. In August 1988 a preliminary procedure was applied to the lower lock gate at Lock and Dam 19 in Keokuk, Iowa. Four Corps experts were involved in this test: Ardine, Atkinson, Midget, and Hickman. Dr. Anthony Kao (USACERL project monitor) was an observer. Lock and Dam 19, located on the Mississippi River at Keokuk, Iowa, is a horizontally framed miter lock gate designed and built by the Corps of Engineers in 1945. Each lower gate leaf is 51 ft tall and 62 ft wide. The lock chamber is 1200 ft long and 110 ft wide. The results of that field test, although primarily qualitative in nature, were used to make several modifications to the initial version of the rating procedure.

146. In October 1988 the second and third field tests were conducted in the Paducah, Kentucky, area by five Corps experts: Atkinson, Hickman, Midget, Steve Moneymaker (Barkley and Kentucky area lockmaster), and Tom Hood (Nashville District Office). Kao was also present. Two different locks and dams were inspected: Kentucky Lock and Dam (upper and lower gates) and

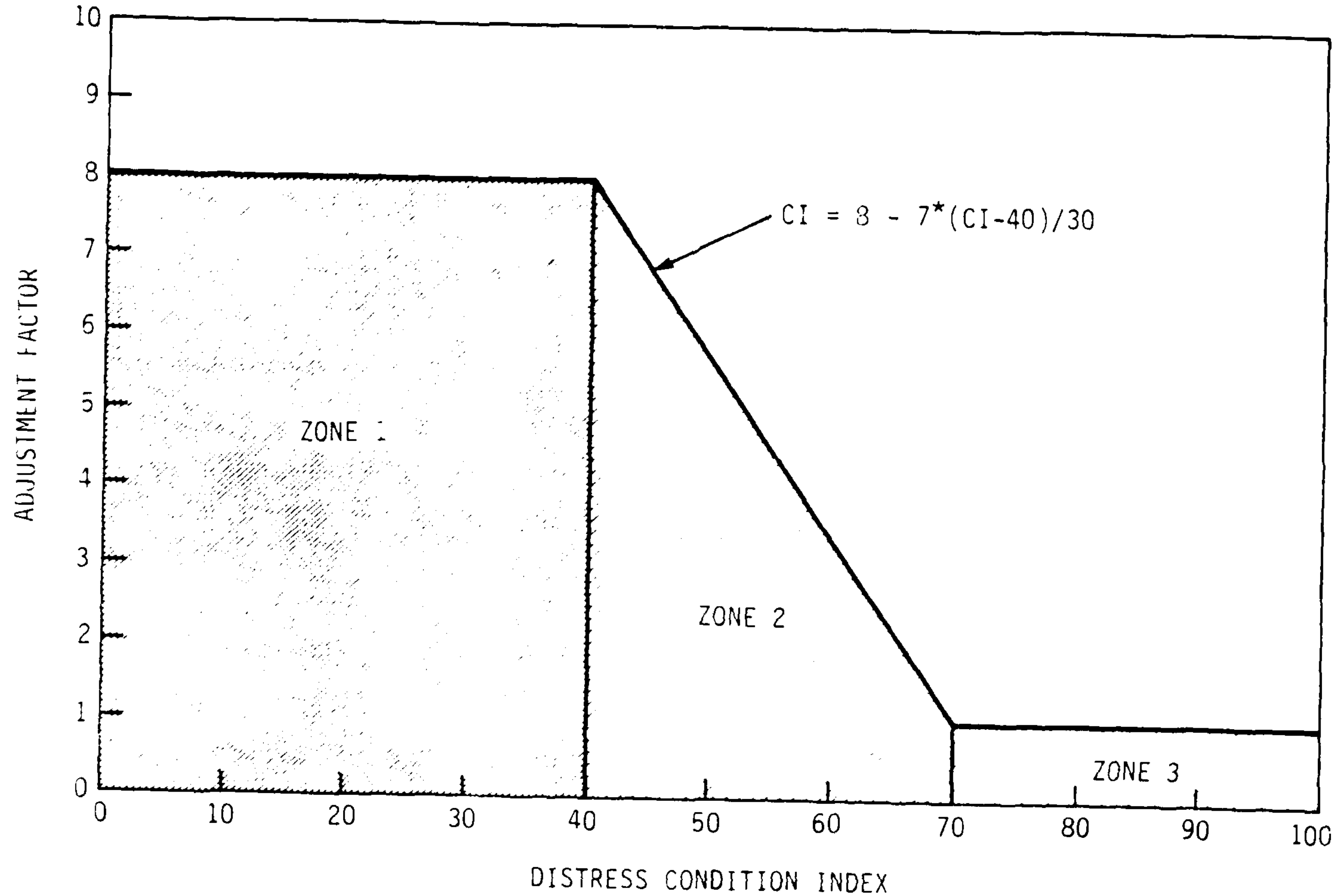


Figure 26. Weight adjustment factor for functional condition index

Barkley Lock and Dam (upper and lower gates). Kentucky Lock and Dam, located on the Tennessee River by Kentucky Lake, Gilbertsville, Kentucky, is a double-skin-plate, horizontally framed, miter lock gate designed and built by the Tennessee Valley Authority (TVA) in 1955. The upper gates are 46.5 ft tall and 62 ft wide. The lower gates are 92.5 ft tall and 62 ft wide. The lock chamber is 600 ft long and 110 ft wide. Barkley Lock and Dam, located on the Cumberland River by Kentucky Lake, Paducah, Kentucky, is a horizontally framed, miter lock gate system designed and built by the Corps in 1958. The upper gates are 50 ft tall and 62 ft wide. The lower gates are 91 ft tall and 62 ft wide. The lock chamber is 800 ft long and 110 ft wide.

147. Each expert was asked to rate the individual distresses in each gate leaf; that is, assign a functional condition index to each distress. Additionally, the experts were asked to assess an overall leaf condition index. Many of the comments and suggestions made during that test have been incorporated into the current version of the procedure. Some adjustments to X_{max} values and weighting values were made to better fit the experts' ratings. The previous portions of Part IV include these changes.

148. The following graphs (Figures 27 through 37) present the expert subjective index versus the calculated functional condition index for the 10 gate leaves in the field test. One graph is presented for each distress. Each graph contains 10 groups of data, 1 group for each of the gate leaves.

ABBREVIATIONS FOR DISTRESS GRAPH COLUMNS

KTKY 1	=	KENTUCKY LOCK:	LOWER	RIGHT	GATE	LEAF
KTKY 2	=	KENTUCKY LOCK:	LOWER	LEFT	GATE	LEAF
KTKY 3	=	KENTUCKY LOCK:	UPPER	RIGHT	GATE	LEAF
KTKY 4	=	KENTUCKY LOCK:	UPPER	LEFT	GATE	LEAF
BRKY 1	=	BARKLEY LOCK:	LOWER	RIGHT	GATE	LEAF
BRKY 2	=	BARKLEY LOCK:	LOWER	LEFT	GATE	LEAF
BRKY 3	=	BARKLEY LOCK:	UPPER	RIGHT	GATE	LEAF
BRKY 4	=	BARKLEY LOCK:	UPPER	LEFT	GATE	LEAF
KEOK 1	=	KEOKUK LOCK:	LOWER	RIGHT	GATE	LEAF
KEOK 2	=	KEOKUK LOCK:	LOWER	LEFT	GATE	LEAF

For example, KTKY 1 is the group of data for the right gate leaf of the lower set of gate leaves at the Kentucky Lock. Within each group of data are four columns of data that represent

- the highest index assigned by an expert
- the lowest index assigned by an expert
- the 3-expert average (Atkinson, Hickman, and Midget participated in all three field tests)
- the computer-model-calculated functional condition index.

An analysis of the comparison of expert rating versus the computer model for each distress, and the overall gate leaf index, follow.

Anchor movement: Figure 27

149. The calculated functional condition indexes of 6 of the 10 gate leaves closely approximate the 3-expert average. The calculated condition index value for three of the remaining gate leaves (KTKY 2, KEOK 1, and KEOK 2) are questionable because of difficulties encountered in making specific and accurate measurements at the dimension points. At Lock 19, the first field test, inadequate apparatus prevented accurate location of the gudgeon pin centerline. Later procedures improved the measurements. The other calculated index value that had a wide variation from the experts was at BRKY 2 where excessive gudgeon pin wear was measured but the wear was not visually apparent.

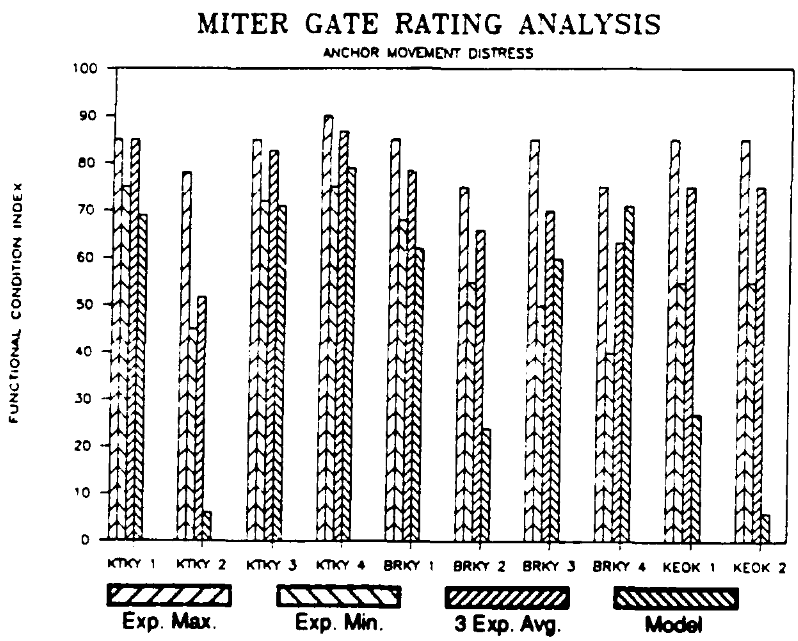


Figure 27. Anchor movement distress

Elevation changes: Figure 28

150. The calculated functional condition indexes of 8 of the 10 gate leaves closely approximate the 3-expert average. In the other two cases, KTKY 2 and KEOK 1, measured elevation changes were observed, calculated, and rated in the upper part of Zone 2 by the computer model, whereas the experts rated the changes in the middle of Zone 1.

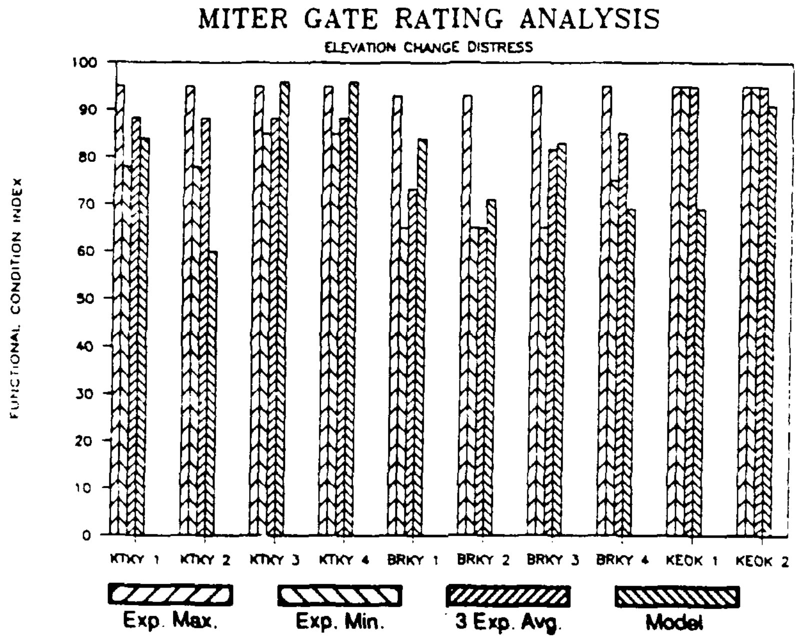


Figure 28. Elevation change distress

Miter offset: Figure 29

151. The calculated functional condition indexes for all 10 of the gate leaves closely approximate the 3-expert average.

Gaps: Figure 30

152. The calculated functional condition indexes of 4 of the 10 gate leaves closely approximate the 3-expert average. Four of the remaining index values are within 15 to 20 points of the 3-expert average. In these four cases, the experts' averages, which were in the mid-90s, suggest that no significant gaps were present. However, the actual measurements with the expert rules do give condition indexes in the lower range of Zone 1. In the remaining two cases, at KEOK 1 and KEOK 2, the measured gaps are partly the result of a preliminary procedure that was adjusted for later field tests.

Longitudinal or Downstream Movement: Figure 31

153. The calculated functional condition indexes of all ten of the gate leaves closely approximate the 3-expert average.

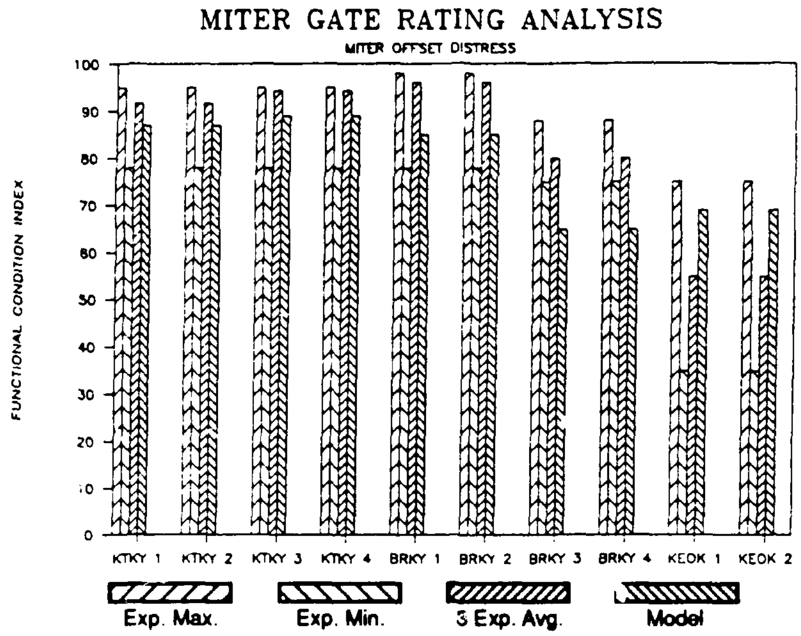


Figure 29. Miter offset distress

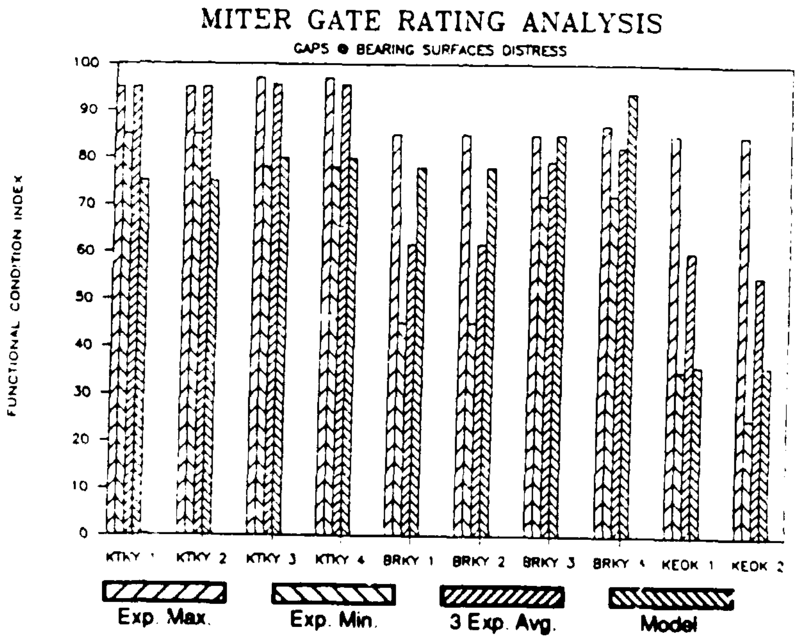


Figure 30. Gaps at bearing surface distress

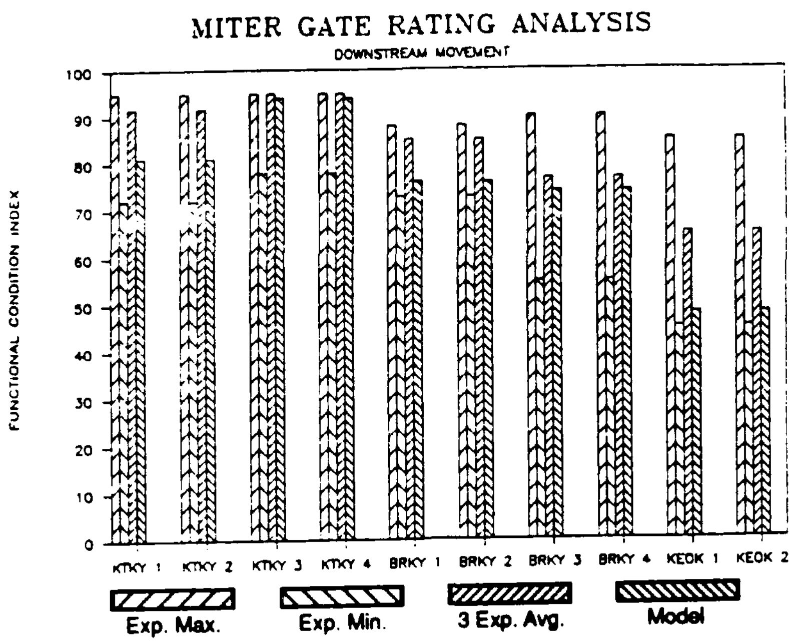


Figure 31. Downstream movement

Cracks: Figure 32

154. The evaluation of cracks, which are another distress, was added to the model after the Lock 19 test. The experts rated cracks on only 4 of the 10 gate leaves; in those cases, the calculated functional condition index closely approximates the 3-expert average. In the remaining 6 cases, the computer model calculated a 100 because no cracks were observed.

Leaks and Boils: Figure 33

155. The calculated functional condition indexes of 6 of the 10 gate leaves closely approximate the 3-expert average. In two other cases, BRKY 3 and 4, minor leaks at the lower sill seal on the upper gate set were recorded as boils. These leaks became apparent as the chamber water level dropped below the upper miter sill. If the minor leaks had not been recorded as boils, the calculated index value would have been very close to the experts' rating. However, the authors think it is appropriate and in fact necessary to record the leak this way. The remaining two cases, KEOK 1 and 2, were very severe leakage conditions and the experts and the computer model both rated the condition severely; that is, in Zone 3, but to a different degree.

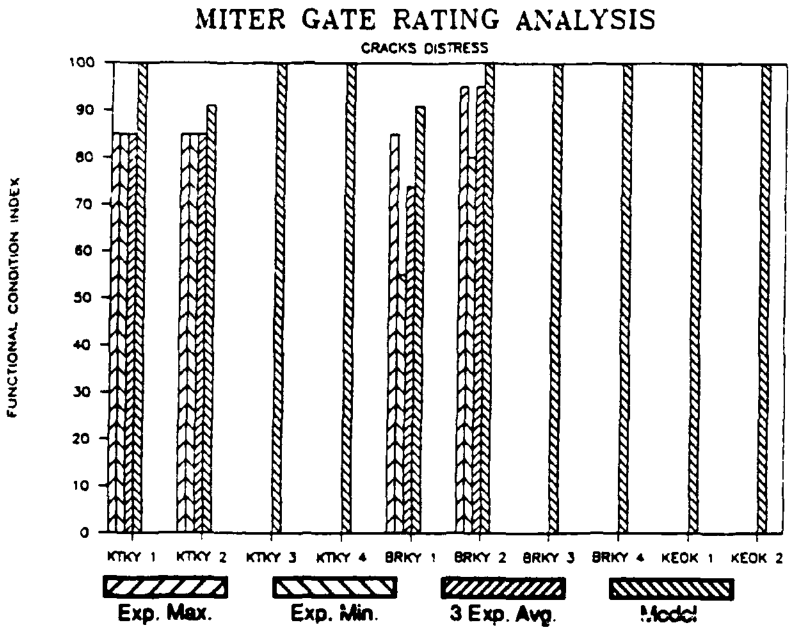


Figure 32. Crack distress

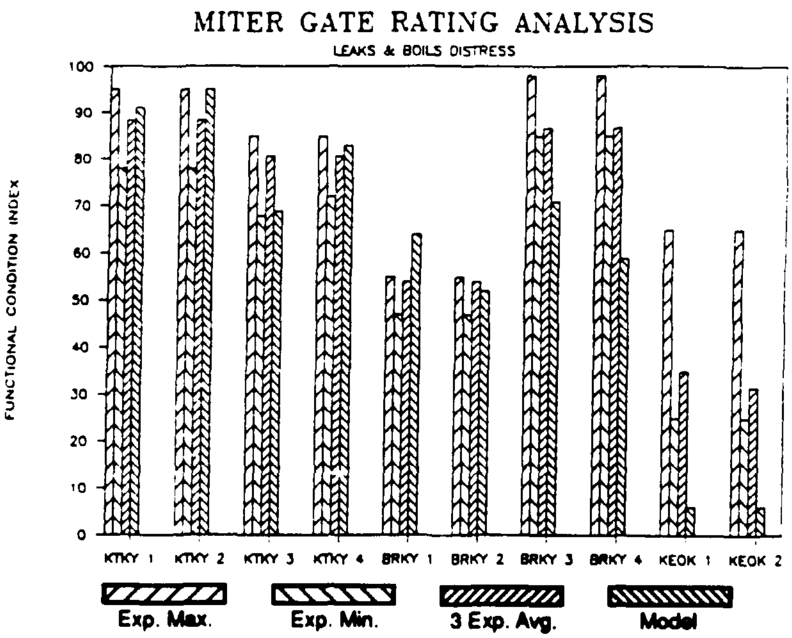


Figure 33. Leak and boil distress

Dents: Figure 34

156. The calculated functional condition indexes of 5 of the 10 gate leaves closely approximate the 3-expert average. In two of the remaining cases, BRKY 1 and BRKY 2, the experts did not put a rating on dents while the computer model calculated a condition index of 100 because no dents were observed. In one case, BRKY 3, one girder dent was observed which, by the distress rules, results in a calculated condition index of 40. However, the three experts did not rate the gate accordingly. In the last two cases, KEOK 1 and 2, no correlation can be made between the 3-expert ratings that ranged from 95 to 25 and the computer model that calculated a condition index of 100 because no dents were observed.

Noise, jump, and vibration: Figure 35

157. The calculated functional condition indexes of all 10 gate leaves closely approximate the 3-expert average. It is noted the experts rated all the gate leaves in the 85 to 95 range even though there were no identifiable occurrences of noise, jumps, or vibrations. The computer model will calculate a 100 index value under those circumstances.

Corrosion: Figure 36

158. The calculated functional condition indexes of 8 of the 10 gate leaves closely approximate the 3-expert average. The remaining two calculated

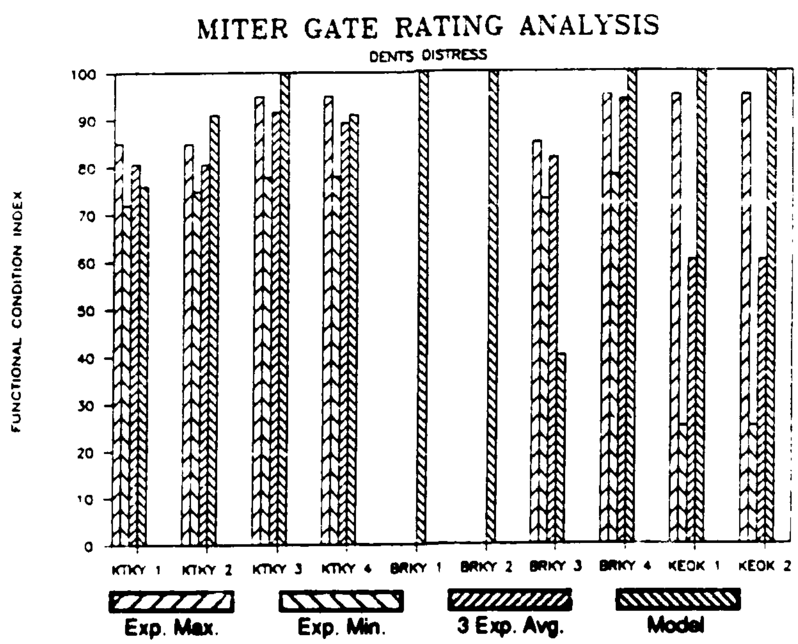


Figure 34. Dent distress

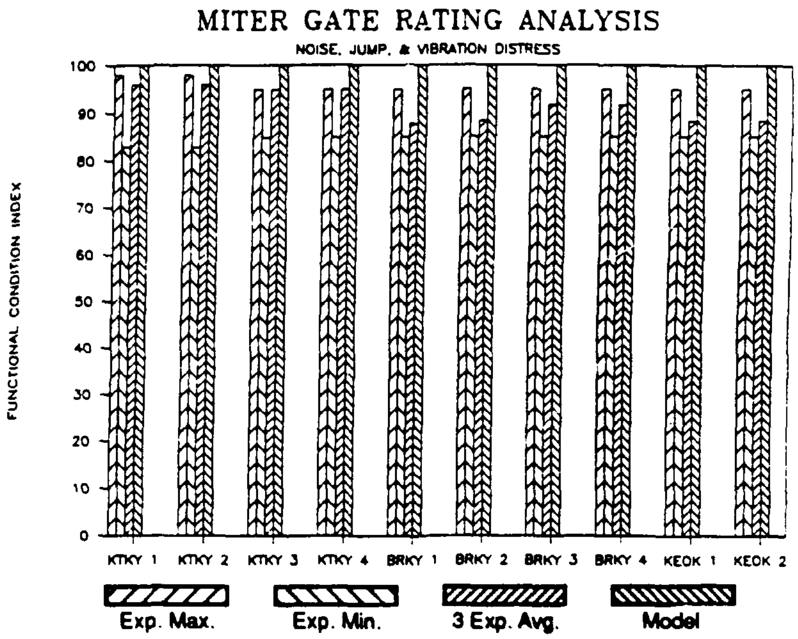


Figure 35. Noise, jump, and vibration distress

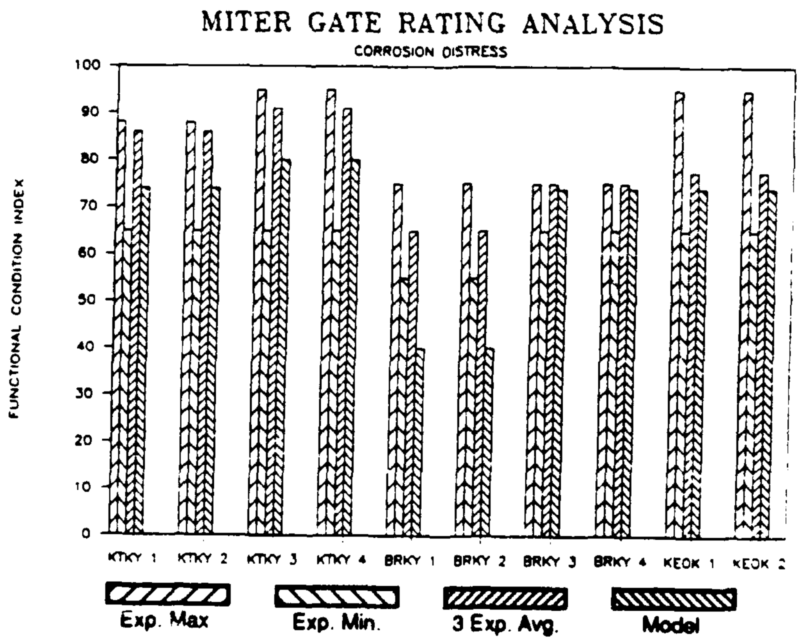


Figure 36. Corrosion distress

indexes at BRKY 1 and BRKY 2 are evaluated at the lowest value of Zone 2 (40), because the downstream girders were judged to have a corrosion level of 3 (X_{max} for girders). This conservative evaluation will highlight the corrosion problem and a subsequent investigation may be in order. A level 2 rating on the girder corrosion level would yield a condition index of 54, closely approx-imating the 3-expert average. This case illustrates the subjective nature that is still inherent in corrosion evaluation.

Overall gate leaf ratings: Figure 37

159. The overall gate rating by the computer model tended to track very consistently with the 3-expert average. Nine of the 10 calculated combined functional condition indexes closely approximated the 3-expert average. In one case, KTKY2, the difference was approximately 20 points. The lower rating by the computer model is directly attributable to the low rating on several of the individual distresses: anchor movement, gaps, and elevation change. These individual ratings lowered the combined index rating as well. While the 20-point differential is not insignificant, the authors believe the computer model reasonably corresponds with the experts' judgment on all 10 of the gate leaves.

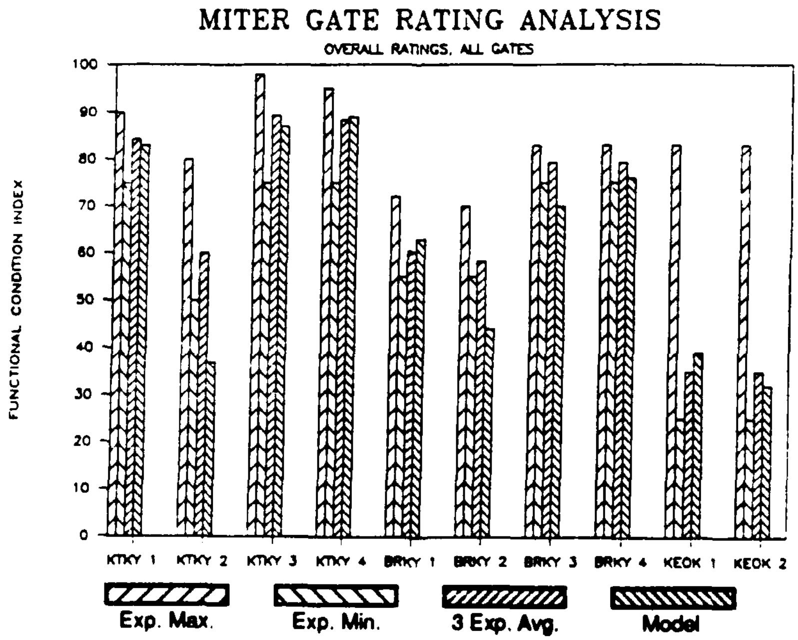


Figure 37. Overall ratings

PART V: DETERIORATION MODEL

160. A deterioration model depreciates the combined condition of a structure from its new or current condition to a future condition. The deterioration model used in this study is an approximation of a rating scheme presented by Markow (1986).

$$\mathbf{CI(t) = A - Be^{Ct}} \qquad \text{[Eq 5.1]}$$

where: CI(t) = condition index in year t
A,B,C = constants

Several factors lead to the deterioration of a miter lock gate (design quality, use, material quality, environment, etc.) making it difficult to predict accurately a time-dependent condition index function. Considering the uncertainties in the prediction, Equation 5.1 can be further simplified to

$$\mathbf{CI(t) = A - e^{Ct}} \qquad \text{[Eq 5.2]}$$

with a slight loss in generality. For a new structure, no deterioration has occurred; that is, CI at a time of zero is 100. Hence, A is 101. If the current condition index of the original structure is CI_1, at time t_1, the constant C becomes

$$C = \frac{1}{t_1} \ell n(101 - CI_1) \qquad \text{[Eq 5.3]}$$

and the predicted deterioration curve for the original structure would be

$$CI(t) = 101 - e^{\left(\frac{t}{t_1}\right)\ell n(101 - CI_1)} \qquad \text{[Eq 5.4]}$$

(See Figure 38 for the shape of the original deterioration curve.) The problem with Equation 5.4 is that on many lock and dam structures, the original miter lock gate is not in place or has undergone several maintenance and repair cycles.

161. Maintenance and repair improves the value of the condition index and creates discontinuities in the deterioration function. Figure 38 shows the original deterioration function interrupted by repair or rehabilitation at time T. The magnitude of the increase of the condition index would depend on

the extent of repair. The assumption in this deterioration model is that repair or maintenance on the miter lock gate restores the gate to a condition and deterioration rate experienced at an earlier time, m, called the equivalent age of the structure. The condition index following repair, CI′, is

$$CI'(t') = 101 - e^{C(t' + m)} \qquad \text{[Eq 5.5]}$$

where: C = constant
t′ = time since last repair or rehabilitation
m = equivalent structure age

Because the deterioration function given by Equation 5.5 has two unknowns, C and m, two separate condition indexes at different times are needed. For this work, the constants will be given by

$$C = \frac{1}{\Delta t}\left|\ell n\left(\frac{101 - CI_2}{100 - CI_1}\right)\right| \qquad \text{[Eq 5.6]}$$

$$m = \frac{1}{C}\left|\ell n(101 - CI_1)\right| \qquad \text{[Eq 5.7]}$$

where: CI_1 = current condition index
CI_2 = condition index at last rehabilitation
Δt = time between last rehabilitation and current

Equation 5.5 represents the predicted condition index since the last rehabilitation, through the current year, and into the future.

162. As an example, a miter lock gate had a condition index of 76 in 1990 following an inspection. It was estimated that the condition index at the last major rehabilitation in 1985 was 82. Solving for the constants C and m gives

C = 0.0549
m = 53.65

The expected value of the condition index for any time t is

$$CI(t') = 101 - e^{(.0549)(t' + 53.65)}$$

where t′ is measured from the last rehabilitation (in 1985).

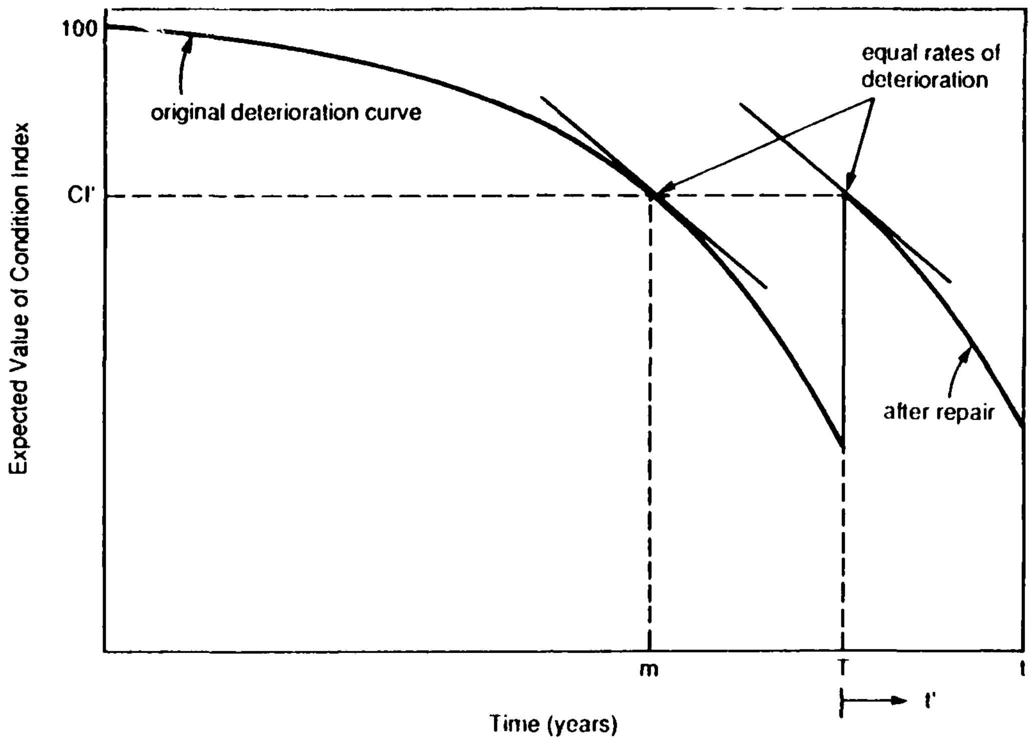


Figure 38. Effects of repair or maintenance on the condition index

PART VI: MAINTENANCE AND REPAIR ANALYSIS

Problems List

163. The inspection and rating procedure is aimed at assessing the current condition of the structure. Through the structural and functional condition indexes, a number of functional and structural problems may be identified for each structure. Each problem is quantifiable either by a field measurement or by a structural calculation. The computer software developed for this project will display a list of problems that were identified during the inspection. The condition index and type of distresses are listed. If the structural calculation produces a factor of safety less than 2.0, a safety problem is also identified on the list.

164. Each problem reduces the performance (safety and/or serviceability) of the structure. As discussed and listed in Parts III and IV, eacn problem can result from one or more of several possible causes. To repair the problem, it is often desirable to know the cause. Frequently, however, the level of inspection does not permit precise determination of the cause. For example, anchorage movement (the problem) can have several causes (embedded anchorage, eye bar connection, gudgeon pin). As another example, a low girder factor of safety could be caused by insufficient downstream flange, insufficient upstream flange, or insufficient longitudinal stiffeners. The software does not diagnose the cause. Each problem is described and possible causes are listed in notes within the software. Engineering judgment is required to look at the information and assess the cause. In some cases, an indepth field inspection with dewatering, diving, or ultrasonic inspections may be required to identify the cause.

Maintenance and Repair Alternatives List

165. For each problem, there is a set of possible maintenance and repair alternatives. Hence, to fix the anchorage movement problem, the embedded concrete could be replaced, the wedge pin adjusted or linkage pin repaired, or the gudgeon pin replaced. The appropriate maintenance and repair alternative often depends on the cause of the problem. Using engineering judgment, the user can select several preliminary alternatives ranging from inexpensive but short-term fixes to complete replacement of the gate. Some alternatives can solve more than one problem. For example, reducing girder stress can reduce effective skin plate stress.

166. Each alternative is described by a note in the software. The list of alternatives and notes can be edited and updated by the user who assigns an

estimated cost and an effective life to each alternative. Engineering judgment, past experience in the district, and the current market value of repair services enter into the cost and life estimate.

Maintenance and Repair Solutions

167. Up to five separate maintenance and repair solutions can be set up within the current software. Each solution consists of a set of maintenance and repair alternatives (Figure 1). Some of these alternatives can be selected from the list described in the previous section. Others can be added. Each solution can involve varying approaches to fixing the problem. One solution could be a do-nothing alternative with no first costs but large, long-term user costs. Another solution may be to replace the entire gate, which corrects all the problems, but at a large initial cost. Other immediate solutions may include maintenance and repair alternatives that fix all of some problems or fix only part of several problems.

168. As emphasized above, the engineer must use judgment when developing each solution from among the alternatives. The program does not isolate cause. Many alternatives can often be eliminated by inspection. Again, it may be necessary to collect additional field or analytical data beyond that recorded on the inspection sheets.

169. The time period for the maintenance and repair solution is entered by the user. Some alternatives may need to be repeated at a regular frequency throughout the time period for the solution. Since the expected life and cost of each alternative have been made available in the previous section, the total initial cost and annualized costs can be computed for the solution. This process will be described in the section on life-cycle cost analysis.

Consequence Modeling

170. All of the maintenance and repair alternatives have consequences with regard to the condition of the structure. Consequence modeling is the part within the maintenance and repair analysis in which the effect of the various solutions on the structural and functional condition indexes are evaluated and a life-cycle cost analysis is performed. The software user is asked to assess the effect of the solution on the distresses and the structural attributes recorded during the inspection. Hence, field inspection data and pages 6 through 9 of the inspection form are displayed one part at a time on the computer monitor. The user is asked to modify the entries to reflect the solution being evaluated. For example, if a wedge pin is being adjusted, the user would reduce the anchorage movement distress. Similarly, if structural features such as coverplates or stiffeners are added, the corresponding

structural entries are modified. The user can request a printout of these modifications as a more detailed explanation of the solution.

171. After the changes have been entered, new structural and functional condition indexes are calculated to quantify the consequences.

Life-Cycle Cost Analysis

172. A preliminary cost analysis can be performed by the program. The current cost and life of each maintenance and repair alternative, the length of analysis period, and the beginning year of the analysis period have been entered in the solution phase of the analysis process. When a life-cycle cost analysis is requested, the user is asked to furnish the interest rate and inflation rate for the analysis period. Length of downtime and out-of-service costs are also requested. With this information the program calculates

$$\textbf{First Cost} = C_{RM} + C_D \qquad \text{[Eq 6.1]}$$

and

$$AnnualCost = \frac{(C_{TRM} + C_{TD})}{AP} \qquad \text{[Eq 6.2]}$$

where:

where:	C_{RM}	=	initial cost of solution (sum of current cost of individual maintenance and repair alternatives adjusted to year of implementation by inflation rate)
	C_{TRM}	=	total cost of solution (sum of initial cost of individual maintenance and repair alternatives incremented by interest rate for the length of the analysis period)
	C_D	=	initial downtime costs (number of days times rate per day)
	C_{TD}	=	initial downtime costs incremented by the interest rate for the length of the analysis period
	AP	=	length of the analysis period in years

Final Solution

173. A printed record of all the information developed in the inspection and rating process and the maintenance and repair analysis are available to the user. Using the consequence modeling results (revised condition indexes), the preliminary cost analysis, and individual judgment, the engineer can make a preliminary selection of a maintenance plan for the miter lock gate. The program and process that have been developed and presented here are useful tools to help an engineer perform an inspection, record the data from an inspection, evaluate the condition of a structure from the inspection data, and perform a preliminary analysis of various maintenance

and repair solutions. However, there are some limitations to the analysis. At this time, the user would be naive to use only the results of this analysis (ratings and costs) as a basis for a final decision.

PART VII. SUMMARY AND RECOMMENDATIONS

Summary

174. The inspection and rating procedure described in this report has intentionally been kept as simple as possible. The inspection requires only simple hand tools such as a tape measure, level, dial gauge, and ruler. An inspection form has been developed for recording historical information (location, previous inspections, or repair history, etc.), structural information (cross sections, water depths, additional loadings, etc.), and distress documentation (offsets, elevation change, corrosion, etc.). Personal computer software has been written to record the inspection information on disks.

175. A condition index is computed directly from the inspection records. The condition index is a number scale from 0 to 100 that indicates the current state of the structure. It is primarily a planning tool that indicates the relative need to perform REMR work. Condition indexes below 40 indicate that immediate repair is required or, possibly, that a more detailed inspection and reanalysis are required.

176. Two separate condition indexes make up the condition index. The structural condition index is a reasonably objective measure of the structural safety. It is related directly to the factor of safety, which is calculated by the PC software. A functional condition index, based on the subjective opinion of several Corps experts, is also calculated. It involves at least two considerations: (1) serviceability, or how the structure performs its function on a day-to-day basis and (2) subjective safety, or how, in the judgment of expert engineers, the safety of the structure has been degraded by various distresses.

177. The inspection and rating procedure has been applied in two field tests (August 1988 and October 1988). The results of these tests have been incorporated into the current version of the procedure.

178. A maintenance and repair analysis phase of the program allows the user to make a preliminary assessment of various alternatives for fixing the structure. A list of problems in the structure is collected from the inspection data. A list of maintenance and repair alternatives within the program can be updated and expanded. The user develops up to five maintenance and repair solutions, each of which consists of a set of maintenance and repair alternatives that solve the associated problems. Initial cost and expected life of each solution are entered. The consequences of each solution are quantified by reevaluating the condition index of the structure. Life-cycle costs of each solution are evaluated after the rates of interest and inflation and downtime costs are furnished.

Recommendations

179. The current inspection and rating procedure for miter lock gate structures has had sufficient development and testing to warrant its distribution on a wider basis. However, it should still be considered developmental. Many of the concepts introduced, such as the structural condition index, the functional condition index, X_{max} values, and weighting factors, should be exposed to a broader range of engineers who work in the area. Modifications to the procedure are certainly expected; suggestions are welcomed.

180. The maintenance and repair analysis presented here represents a significant tool to be used by experienced engineers to help them arrive at maintenance and repair decisions. It, too, is ready for an initial distribution and evaluation by the Corps community. It should be considered as a preliminary version, as a step in an evolutionary process. As with all engineering analyses, numerical results should not be interpreted too literally, but considered in the light of "engineering judgment." (See page 8, para 5 for information on software and assistance concerning this material.)

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APPENDIX A: USERS' GUIDE

(See page 8, para 5 for information on software and assistance concerning this material.)

Overview

1. An overview of the inspection and rating process and the maintenance and repair analysis is presented in Chapter 1. Once the program has been installed on a personal computer (PC), it is menu-driven. All operations including file management, operation selection, and summary report writing are controlled by menu selection. This appendix will show you how to use most menus and what to expect from certain selections. Because of the many combinations and permutations of paths through the menus, not all possibilities can be illustrated. Figure A1 illustrates the three primary menus and the general procedure for using the MITER program. The steps that are listed in Figure A1 correspond with those in Figure 1 of the main text. Each of the steps is described in more detail in the following sections.

Notation Conventions

2. The following notational conventions are used throughout this guide:

   a. **BOLDFACE CAPITAL LETTERS** - File names, directory names, and DOS commands are printed in boldface capital letters.

   b. **Boldface lower-case letters** - User selection options are emphasized by lower-case boldface letters.

   c. Underline - Menu names and window names are identified by underlining.

Installation of MITER

Hardware requirements

3. The following computer hardware is required as a minimum:

   a. An IBM-PC-compatible personal computer.

   b. At least 640 kilobytes (Kb) of random access memory (RAM).

   c. A hard disk.

The amount of disk space you should reserve on the hard disk depends on the number of projects that you will record on the system. The executable programs associated with MITER require approximately 1000 Kb of disk space. Each miter lock gate structure requires 150 Kb of disk space. A project, however, could have one or several structures. Therefore, 10 projects would require at least 1500 Kb of disk space. Initially, it is recommended that you reserve a minimum of two megabytes (Mb), which will accommodate the program and three to six projects containing two structures.

Customizing MS-DOS for MITER

4. To run MITER on a MS-DOS operating system, you will need to extend some of the defaults. Generally, this modification will also improve performance of the other programs on the system. Change the operating system defaults by modifying the **CONFIG.SYS** file in the root directory of the system. Include the following statements in the **CONFIG.SYS** file:

FILES=20

BUFFERS=20

DEVICE=path\ANSI.SYS

BREAK=ON

where path is the file path to **ANSI.SYS**. If the **CONFIG.SYS** is not already on the root directory of the system, create it using any text editor that produces a standard DOS text file (ASCII file). For example, you can use **EDLINE**, which comes with the DOS, to create the file. Be sure to place the **CONFIG.SYS** in the root directory of the C: drive.

Installing MITER on the computer system

5. The program MITER is distributed on 5-1/4 in. 360K floppy disks. The installation utility program will automatically install the MITER program and support files on the C: drive of the computer. The utility program **INSTALL.BAT** starts on Disk A of the diskette set and continues on each disk. **INSTALL.BAT** executes DOS commands to create a directory called **ISUPROJ** on the root directory and several subdirectories. To install MITER:

a. Make sure the computer is on and the DOS prompt is displayed.

b. Place the MITER program distribution Disk A in Drive A:

c. Type **A:INSTALL.BAT** and press **ENTER**. Each disk will prompt for the succeeding disks automatically. Several data and project directories are created and the 14 executable modules that make up MITER are copied to the main directory **ISUPROJ**.

If you wish to install MITER on a drive other than C:, or use another name for the MITER directory, you must either modify **INSTALL.BAT** or install MITER manually. This guide assumes that you have used the unmodified **INSTALL.BAT** to install MITER and use **ISUPROJ** to refer to the MITER directory.

Organization of project files

6. The MITER program and all related project data files are normally installed one level down from the root directory on the C: drive of the computer system in a directory called **ISUPROJ**. All executable program files and program support files are at this directory level.

7. The MITER program has been designed to operate at the project level. The organization of projects and MITER inspection data files use the DOS hierarchy structure of subdirectories. Project files are identified and organized into separate subdirectories in the directory **ISUPROJ**. For example, the project Barkley Lock & Dam located at Grand River, Kentucky, on Barkley Lake Waterway system has two miter lock gate structures, one being the upper

gate. The project inspection data files for the Barkley Lock upper gate would be organized in the following manner:

```
Root directory
 ├─ISUPROJ                    program directory
 │   ├─BARKLEY LOCK           project subdirectory
 │   │   ├─UPPER GATE         MITER structure subdirectory
 │   │   │    │ FILES         structure data files
 │   │   └─LOWER GATE
 │   └─another project
```

This organization of project inspection data files allows multiple MITER structures under a particular project name and clearly maintains the integrity and transportability of individual project files. You can readily copy the inspection data from the hard disk system to archive data files or to transport to another system.

8. Other subdirectories under **ISUPROJ** are not project files but are required to support the maintenance and repair analysis module of MITER. They are called **DATA** and **TEMP** and support all the project files, not a specific project file. If you transport individual inspection data files to another system, the maintenance and repair modeling solutions can only be transported by paper copy and then reentered on the new system. However, if you are making a system change and all the projects are being transported, then routine DOS file handling techniques will transport the data as a directory block.

9. It is possible for you to organize the data at a higher system level, such as a waterway system by renaming the program directory level to a waterway system acronym, for example, **ILLRVR** for Illinois River waterway. The program does not readily support this system level of project organization, but you can accomplish it by installing the MITER program in each waterway system directory. Each time the MITER program is installed, it requires approximately 1000 Kb of disk space.

Project identification

10. Using the DOS subdirectory hierarchy places a restriction on the freedom of naming project structures. Each project name or structure name is limited to eight characters and also to DOS conventions. If you are unfamiliar with DOS conventions and encounter difficulty, refer to the DOS system manual for guidance.

11. In the example project used in the manual, the project name used was **BARKLEY** and the structure name was **UPR_GATE**, short for upper gate.

General procedure starting and using MITER

12. Figure A1 illustrates the three primary menus that

a. control the flow of the program,

b. input data from the inspection form,

c. calculate the condition index,

d. perform deterioration analysis, and

e. evaluate maintenance and repair options.

Figure A2 follows Figure A1 and is a flow diagram through the three primary menus as well as several submenus.

Getting started

13. At the system prompt, change the directory to **ISUPROJ**: Type **project** and press **ENTER**. The screen will display the Main Menu (see Figure A3).

14. You select **2 - Analyze miter lock gate** and proceed to the next selection menu, Figure A4. Figure A4 illustrates the file maintenance menu that keeps the project data structure.

1 - Select an existing project from the list allows you to select a project and structure from the list that appears in the Projects on this data disk window. (See Figure A5 for an example.)

2 - Create a new project to work on sets up a new directory and subdirectory for a new projects data file and adds the name to the project list. NOTE: This procedure must be used to create directories or the project name will not appear on the project list and cannot be accessed by MITER. (See Figure A6 for an example.)

3 - Delete a project from this disk displays the project list window for you to select the project. You will be prompted to confirm the removal of the selected project. NOTE: This procedure must be used to delete a project or the name will not be deleted from the project list.

15. Following selection of a project, the program will proceed to the Miter Gate Analysis menu (Figure A7).

NOTE: The first selection **1 - Analyze steel sheet pile** is also functional in this distribution (Greimann, 1988).

16. The Miter Gate Analysis menu provides the functions to input, store, and print data; to compute condition indexes; and to go to the maintenance and repair menu.

1 - Create new structure data files is the data input function to transfer inspection data into the computer.

2 - Update current structure data files is the data editing function to change or add to inspection data.

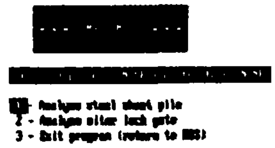
3 - Print current structure data files is the print function to produce documentation and reports, including condition indexes, if they have been calculated.

4 - Compute functional condition index performs calculations.

5 - Compute structural condition index performs calculations.

6 - Display summary report is a screen display of basic project identification and the computed condition index.

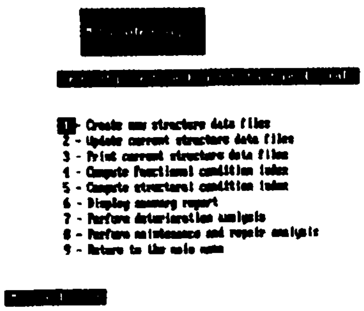
7 - Perform deterioration analysis is a module to view the condition index versus time.



1. Select operation to perform
   e.g., **2-Analyze miter lock gate**.

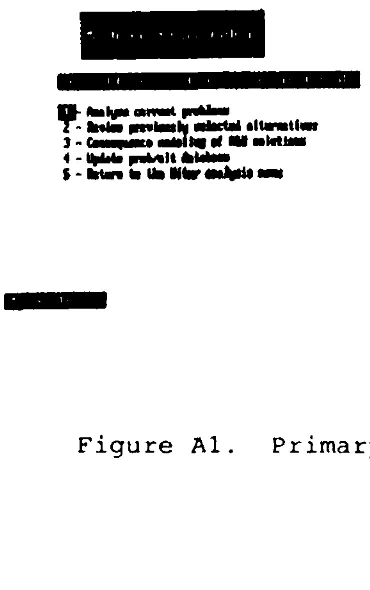
2. Select project
   Use 1 to **Select existing project**
   Use 2 to **Create new project**
   Use 3 to **Delete existing project**
   Use 4 to **Return to main menu**.

3. Compute condition indexes
   4-Compute functional condition index
   5-Compute structural condition index



4. Review condition index summary
   6-Condition index summary report
   You must diagnose the problems that have been identified and understand why the condition indexes are as reported.

5. Perform deterioration analysis
   7-Perform deterioration analysis
   You can determine the effects of delayed maintenance.



6. Review maintenance and repair (M&R) options
   8-Perform maintenance and repair analysis
   a. Develop M&R solutions
      1. Analyze current problems, or
      2. Review previously selected alternatives
   b. Analyze and model M&R solutions
      3-Consequence modeling of M&R solutions
   c. Review results of analysis and modeling to recommend maintenance or repair management.

Figure A1. Primary menus for MITER and procedure guide

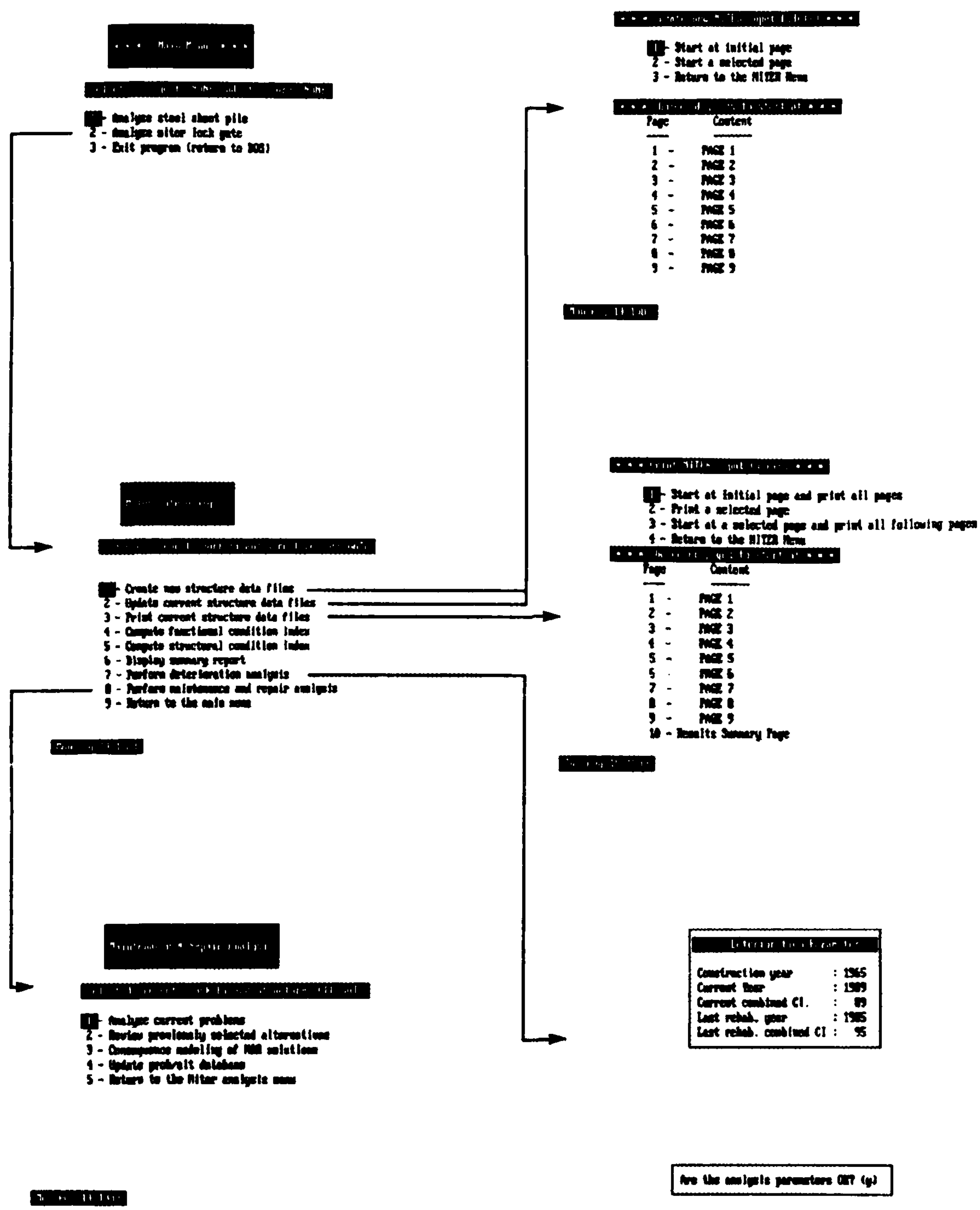


Figure A2. Organization of MITER menus

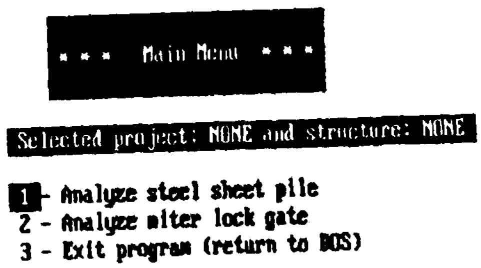


Figure A3. Main menu

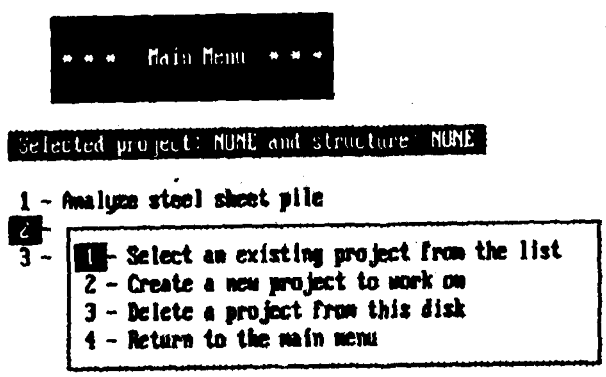


Figure A4. File maintenance menu

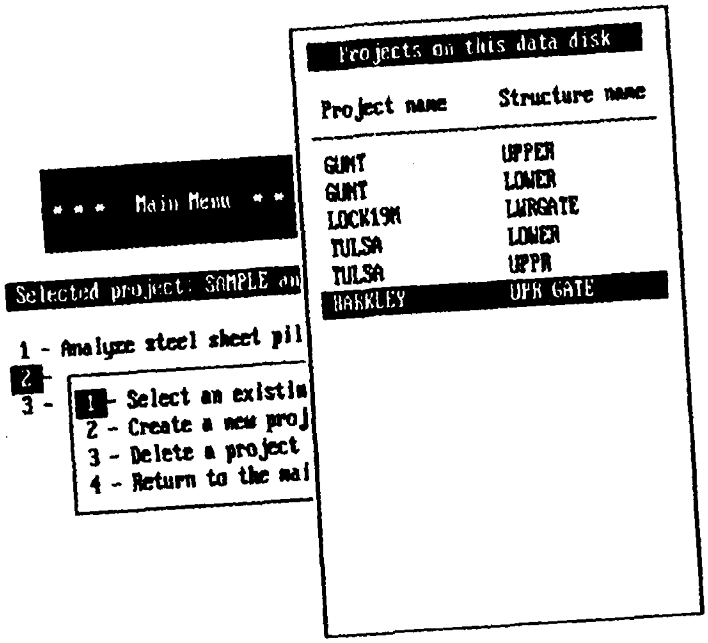


Figure A5. <u>Projects on this data disk</u>

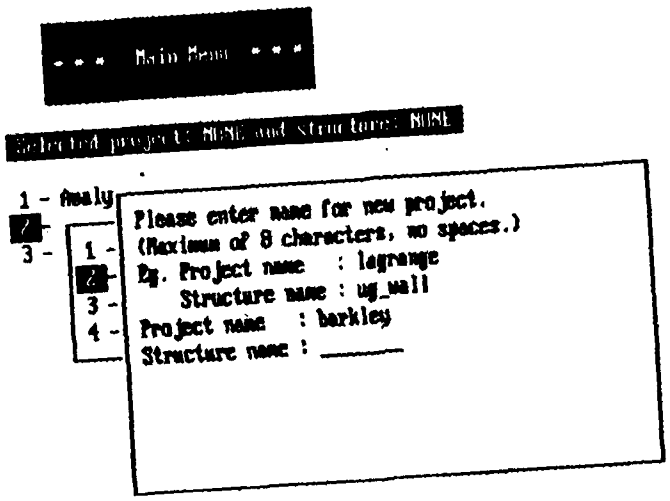


Figure A6. <u>Create new project files</u>

Miter Gate Analysis

Selected project: BARKLEY and structure: UPR_GATE

1 - Create new structure data files
2 - Update current structure data files
3 - Print current structure data files
4 - Compute functional condition index
5 - Compute structural condition index
6 - Display summary report
7 - Perform deterioration analysis
8 - Perform maintenance and repair analysis
9 - Return to the main menu

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Figure A7. Miter gate analysis menu

8 - **Perform maintenance and repair analysis** is a module to assist in the development of maintenance and repair solutions.

9 - **Return to the main menu** returns to the previous menu.

Inspection Form Input

17. Selecting **1 - Create new structure inspection files** is the data input function that creates data files under the selected MITER structure subdirectory. The subdirectory is the storage space for the inspection data.

18. Three rules apply to the input of data and must be adhered to.

Rule 1: Your must create each page of data with this selection. You may stop after page 3 to edit page 1, but create must be used to start entering data at page 4.

Rule 2: Pages 1 through 5 must exist before the program will allow you to calculate the functional condition index.

Rule 3: Pages 1, 5, and 6 through 9 must exist before the program can calculate the structural condition index. Page 5 has to be created even when there is no functional data; in this case enter zeros (0) in the corrosion entries.

19. Selecting **2 - Update current structure inspection files** is the data editing function to change or add to recorded inspection data. A submenu for **Update** is very similar to Figure A8.

20. The following section has specific details about entering and editing data to the MITER structure data files.

Data entry

21. The MITER program is fully menu-driven and guides you through the pages of forms in a straightforward manner. MITER does perform an error check on certain data fields that must have restricted input of a particular character or number. The error checks are these:

a. Only allowable characters are accepted; illegal characters are rejected with a "beep."

b. A valid range check is performed on some numeric data at the completion of the entry. If the number entered is out of range, MITER will "beep" and prompt you to enter the data again. Valid data must be entered in order to move on to the next data item.

The majority of the data entries are not restricted.

Editing data

22. After the data is entered, you will find it necessary to edit the data. Some of the typical word processor routines work well, but a review of those useable in this program is helpful.

```
* * * Create new MITER input file(s) * * *

    1 - Start at initial page
    2 - Start a selected page
    3 - Return to the MITER Menu

* * * Choice of pages to start at * * *
    Page        Content
    ----        -------
    1 -         PAGE 1
    2 -         PAGE 2
    3 -         PAGE 3
    4 -         PAGE 4
    5 -         PAGE 5
    6 -         PAGE 6
    7 -         PAGE 7
    8 -         PAGE 8
    9 -         PAGE 9
```

Figure A8. Create MITER data files

a. Changing data entry mode: MITER supports two different modes for data entry: the "Insert" and "Overwrite" modes. In the "Insert" mode, the characters that you type are inserted at the current cursor location, whereas in the "Overwrite" mode, the character at the cursor is replaced with your entry. Press **INSERT** key to toggle between the "Insert" and "Overwrite" modes. The cursor symbol for the "Insert" mode is a small flashing square, whereas the cursor for "Overwrite" mode is a flashing underscore character. The default mode is the "Overwrite" mode.

b. Cursor Control: Several commands are available for moving within the data entry line for editing:
- Use the **RIGHT** or **LEFT** arrow keys to move right or left by one.
- Use the **CTRL-RIGHT ARROW** or **CTRL-LEFT ARROW** keys to move a word right or left.
- Press **HOME** key to go to the beginning of the line.
- Press **END** key to go to the end of the line.

c. Delete: Press **DEL** key to delete a character at the cursor position and **BACKSPACE** key to delete a character to the left of the cursor position.

23. Selecting **3 - Print current structure inspection files** will display the submenu in Figure A9.

Condition Index Calculation

24. Selecting **4 - Compute functional condition index** performs the calculation of observed distress measurements versus the "expert rules" embedded in MITER.

* * * Print MITER input file(s) * * *

1 - Start at initial page and print all pages
2 - Print a selected page
3 - Start at a selected page and print all following pages
4 - Return to the MITER Menu

* * * Choice of pages to start at * * *

Page	Content
1 -	PAGE 1
2 -	PAGE 2
3 -	PAGE 3
4 -	PAGE 4
5 -	PAGE 5
6 -	PAGE 6
7 -	PAGE 7
8 -	PAGE 8
9 -	PAGE 9
10 -	Results Summary Page

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Figure A9. Print MITER data files

FUNCTIONAL CI : MITER GATE

Condition Index		Right Gate	Left Gate
ANCHOR SYSTEM	:	60	71
LONG. MOVEMENT	:	74	74
NOISE JUMP	:	100	100
OFFSET	:	65	65
GAP	:	85	94
CORROSION	:	74	74
DENTS	:	40	100
CRACKS	:	100	100
LEAKS & BOILS	:	70	58
ELEVATION	:	83	69
COMBINED	:	70	76

Hit <C> to Change weight factors
or any other key to continue. .

Figure A10. Functional condition index window

25. The functional condition index window (Figure A10) lists the observed distresses and the calculated functional condition index for the left and right gate. These data are also summarized in the condition index summary report. The number of occurrences is later read into the maintenance and repair module Problem List (Figure A15). Please refer to Part IV for details about the functional condition index.

26. Selecting **5 - Compute structural condition index** performs the calculation of the minimum factors of safety. The computed condition indexes and the location of the most critical sections are displayed in the Structural CI window displayed in Figure A11. Refer to Part III for details about the structural condition index.

27. Selecting **6 - Condition index summary report** will provide you with a screen display of basic project identification and a summary of the condition indexes. This selection is a quick way to see more data about the project without performing three separate operations. The summary report is reproduced in its entirety as print choice, Page 10 - Results Summary.

28. Selecting **7 - Perform deterioration analysis** allows you to view a time-dependent condition index. The deterioration parameters (Figure A12) are required input data for the deterioration curve. You have several graphic options as shown in Figure A13. Selection of the regular line graph is the most common. Refer to PART V for details about the deterioration function.

STRUCTURAL CI

LC	INTERCOSTAL	PNL #	SKIN	PNL #	GIRDER	GRDR #	MINIMUM
1	100.	10	100.	6	83.	7	83.
2	100.	10	100.	6	100.	7	100.
3	100.	2	100.	2	100.	2	100.
4	100.	2	100.	1	100.	2	100.
6	100.	10	100.	6	100.	7	100.
					STRUCTURAL CI		83.

CORROSION MODIFIED STRUCTURAL CI — RIGHT GATE

INTERCOSTAL	SKIN	GIRDER	MINIMUM
100	100	61	61

CORROSION MODIFIED STRUCTURAL CI — LEFT GATE

INTERCOSTAL	SKIN	GIRDER	MINIMUM
100	100	61	61

Hit <p> to print detailed structural analysis
or any other key to continue. . .

Figure A11. Structural CI

Deterioration Parameters

Construction year : 1965
Current Year : 1989
Current combined CI. : 89
Last rehab. year : 1985
Last rehab. combined CI : 95

Are the analysis parameters OK? (y)

Figure A12. Deterioration parameters

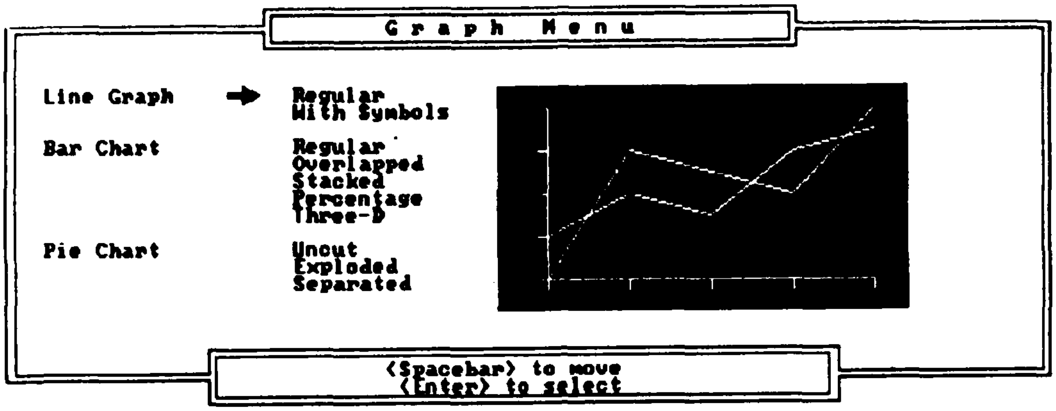

Figure A13. Deterioration graph menu

29. Selecting **8 - Perform maintenance and repair analysis** is discussed in detail in the next section.

30. Selecting **9 - Return to the main menu** returns you to the beginning of the MITER program to end the session or select another project.

Maintenance and Repair Analysis

31. Selecting **7 - Perform Maintenance and Repair Analysis,** at the Miter Lock Gate Analysis menu (Figure A7) allows you to define multiple scenarios for maintenance and repair of problems or deficiencies observed in the inspection or identified by the condition index evaluation. Each of these scenarios, or Maintenance & Repair (M&R) solutions, enables you to fix, correct, or replace problems or deficiencies by selecting alternatives and building M&R solutions. The solutions may be little fixes, like gate adjustment, or big fixes, like adding intercostals. You can then model each of the M&R solutions to evaluate the improvement in condition index as a result of the fix. You can also perform life-cycle cost analysis (LCCA) to evaluate relative costs of each scenario or M&R solution.

32. Figure A14 illustrates the menu to begin M&R Analysis. The selected project is displayed and five menu choices are available to control the M&R procedure.

1 - **Analyze Current Problems** is the selection to create or add new M&R solutions to the project files.

2 - **Review Previously Selected Alternatives** is the selection to review the list of previously defined solutions.

NOTE: A maximum of five M&R solutions can be active on a file for any one project structure. You may edit existing M&R solutions to redefine another M&R solution or may delete alternatives from an existing M&R solution and start fresh.

3 - Consequence Modeling of the defined M&R solutions. This allows you to analyze the impact of each M&R solution and is discussed in detail later in the manual.

4 - Update Problem/Alternatives Data Base allows you to edit or add to the initial M&R alternatives data base.

NOTE: This particular function must be used carefully. The problem list is predefined for a structure type. Only the M&R alternatives should be added to or revised. This process will be described in more detail later in the manual.

5 - Return to the MITER analysis Menu allows you to allows you to back up one level to the <u>MITER Analysis menu</u>.

<u>M&R solutions</u>

33. Selecting **1 - Analyze Current Problems** will display a blank form (Figure A15) for you to begin developing an M&R solution. The first procedure is to select several analysis parameters that are specific to this M&R solution. You are prompted to input or edit the parameters.

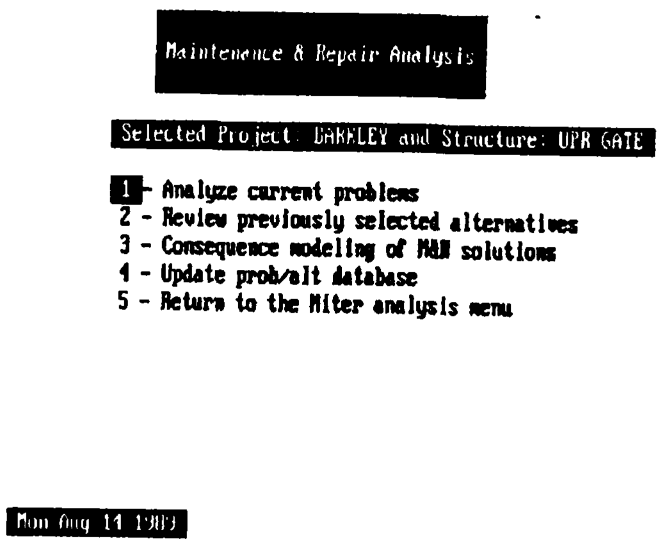

Figure A14. <u>Maintenance & Repair Analysis menu</u>

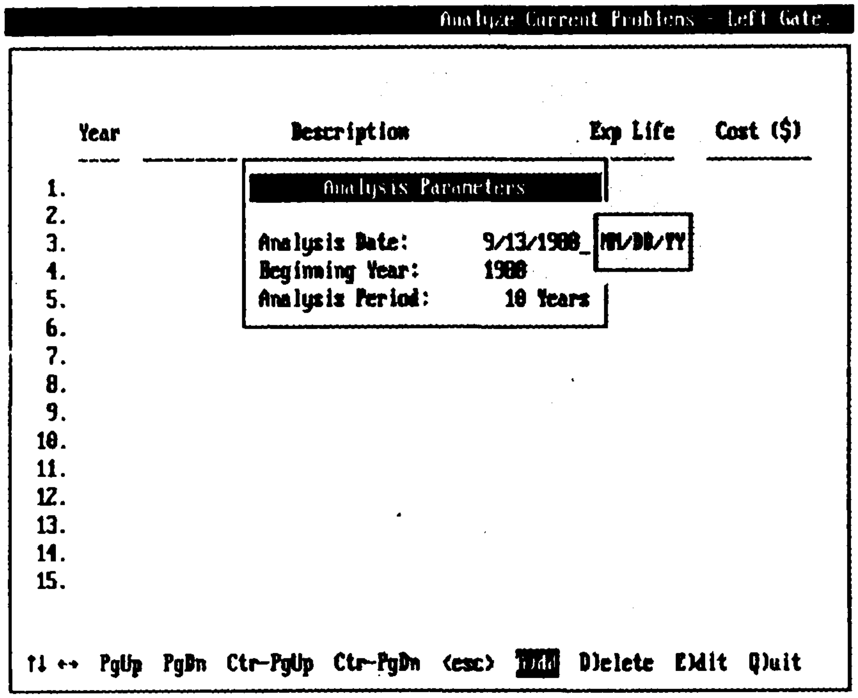

Figure A15. Analysis Parameters

34. The parameters are

- Analysis Date: Date of the analysis, for future reference.
- Beginning Year: First year for the analysis period; it can be the current year or a future year. This date is used as the initial year in the life-cycle cost analysis.
- Analysis Period: Length of the analysis period, for example, 1 year, 5 years, or 20 years.

After the analysis parameters are correct, select (**yes**) and the program automatically goes to the next selection level, where the Problem List window appears.

M&R solution form

35. At this point, a brief explanation of the background form is in order. Figure A16 shows the blank form that is the basic building block for each M&R solution. The normal operation will not display this screen with all blank rows. Normal operation will have a selection window displayed, such as Analysis Parameters (Figure A15) or Problem List (Figure A17) or have selected alternatives displayed for action. Features of the form follow:

a. The title line informs you whether the form is in a mode to analyze current problems (for creating a new solution), or in a mode to review current problems (edit an existing solution).

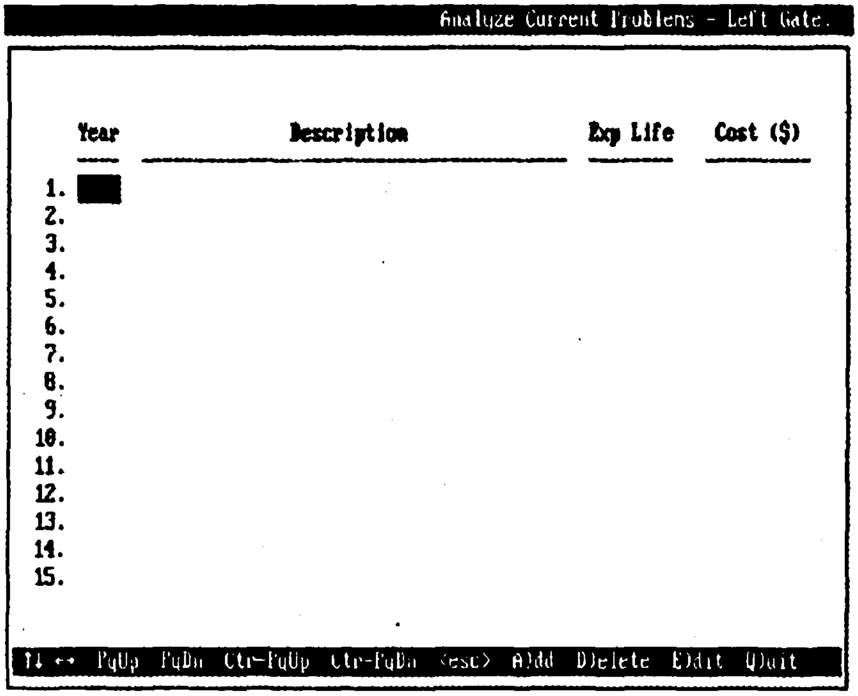

Figure A16. <u>M&R solution form</u>

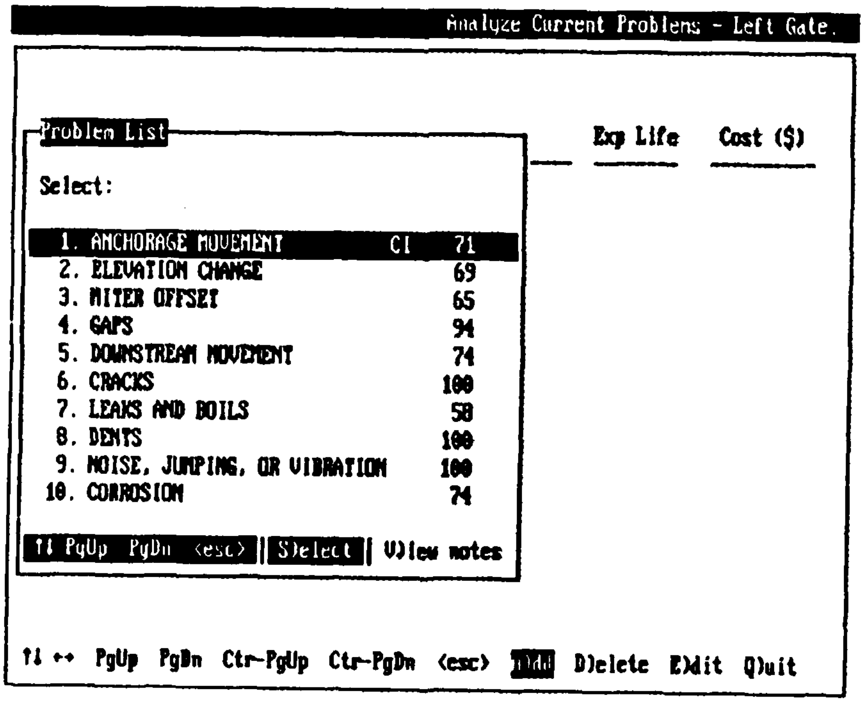

Figure A17. <u>Problem List window</u>

b. Columns allow input of the year, description, expected life, and cost ($) of the selected alternative. A more detailed description of the input in each column will be given in a later section.

c. Active user option keys are displayed at the bottom of the screen and described in the following paragraphs.

36. If all selections in the row are highlighted, it means all the selection keys are active. If only one is highlighted, for example, **Edit**, the form is in edit mode at the location of the cursor in the form. The default location of the cursor is in the first column of row one. The cursor can be moved to other locations in the form to execute option keys. The cursor movement keys act as follows:

a. **Arrow** keys move the cursor from row to row or field to field.

b. **PgUp** or **PgDn** moves the cursor between window pages.

c. **Ctr-PgUp** and **Ctr-PgDn** moves the cursor only if there is more than one page of alternatives. **Ctr-PgUp** will return the cursor to the default location at row one. **Ctr-PgDn** will move the cursor to the top row of the last full screen page display.

37. The remaining option key actions depend on the location of the cursor within the M&R solution form.

a. First case: When the cursor is in a row that is not blank, then
- **<esc>** or **Edit** enters edit mode at the cursor location
- **Add** inserts a blank row at the cursor location and displays the Problem List window (Figure A17) for selection of an alternative, and
- **Quit** ends the selection process and exits to save the M&R solution.

b. Second case: When the cursor is in a row that is blank (e.g., the row below a list of alternatives or a blank form), then:
- **<esc>**, **Add**, or **Edit** displays the Problem List window (Figure A17) for selection of an alternative, and
- **Quit** ends the selection process and exits to save the M&R solution.

Continue to the next selection level where the Problem List window appears.

Problem list

38. A typical problem list (Figure A17) has been developed for a project structure, in this case, miter lock gates. The typical problem list for miter lock gates includes 13 problem definitions that are displayed each time this screen appears. The list of problems that appears may be more than one page long, as is the case with miter lock gates. You can view or select from the problems on the second page with cursor movement. The project inspection data file is used to generate the list. The example window lists the structural and functional problems and the corresponding condition indexes.

39. At the bottom of the Problem List window are active user keys including cursor movement keys and option keys. The cursor movement keys act as follows:

- a. **Arrow(s)** up and down move the cursor from line to line on the displayed window page.

- b. **PgUp** and **PgDn** move the cursor between window pages.

40. The option keys act as follows:

- a. **<esc>** returns to the background M&R solution form.

- b. **Select** calls for the M&R Alternative List window to be displayed. The contents of this list are dependent on the problem list (see the next section). You select the problem by moving the cursor to the specific problem line and pressing **ENTER**. This is the default option key.

- c. **View notes** is an option to see more information about a problem. This option is activated by typing **V** to select view notes and then **ENTER**. A window will display notes pertaining to the selected problem. (See Figure A18.)

Developing an M&R solution

41. Develop the M&R solution by selecting a problem from the Problem List and a corresponding maintenance or repair procedure from the M&R Alternative List (Figure A19). You can refer to the inspection form to identify specific details about the problem location, severity, and so on, and then

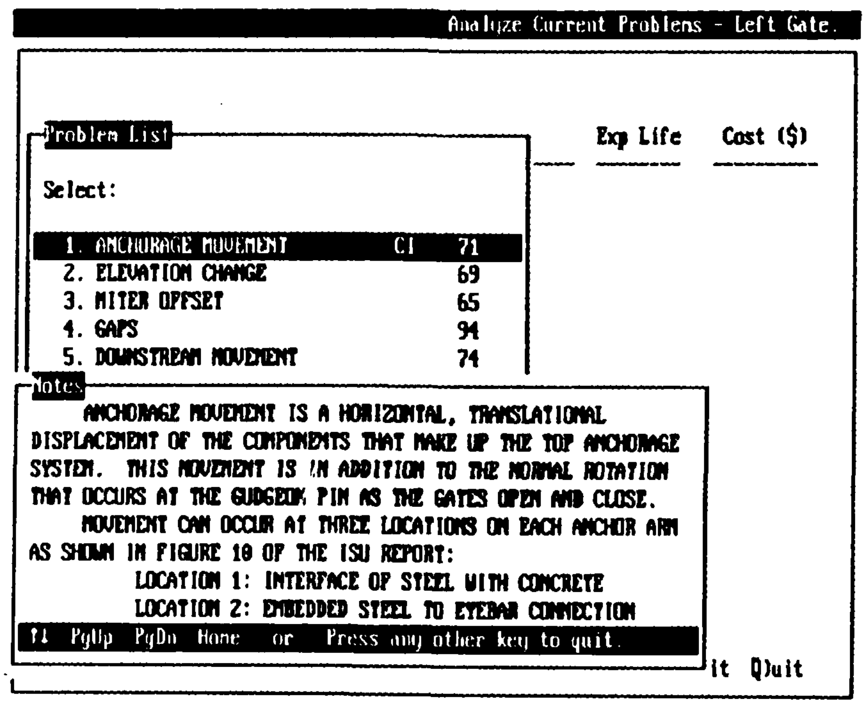

Figure A18. Notes window

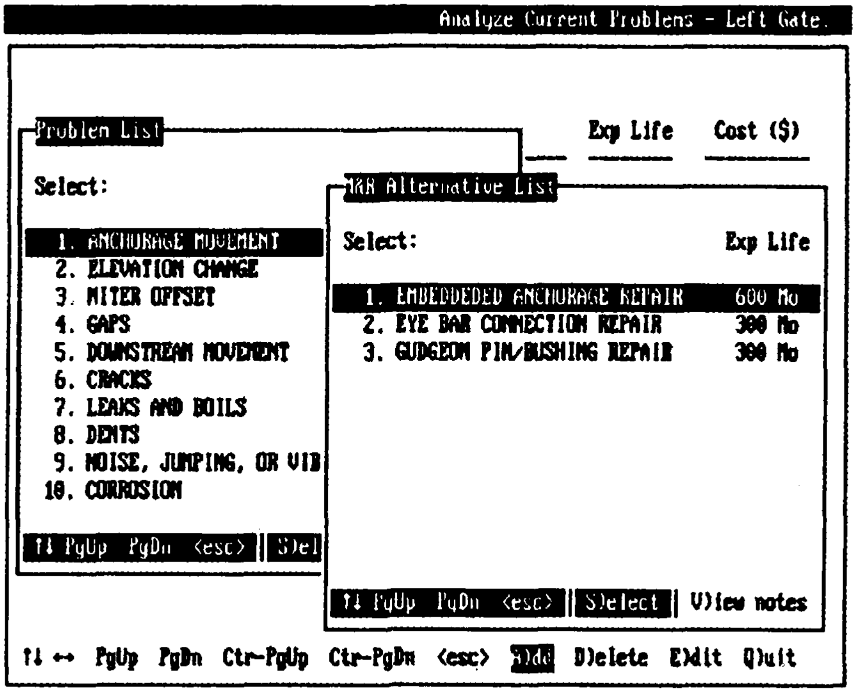

Figure A19. M&R Alternative List window

make decisions about which problems to solve in a specific M&R solution. You can define up to five different M&R solutions for analyzing in consequence modeling. Each M&R solution can be edited, added to, etc., before consequence modeling or after modeling, to study a different approach.

M&R alternative list

42. The M&R Alternative List, which is the right-hand window in Figure A19, is a list read into the M&R module from the problems and alternatives data file. The data list is typical for all projects of like structure type; in this case miter lock gate. The list of M&R alternatives that appears may be one alternative or more than one page of alternatives. The description of each M&R alternative is brief and is intended to be edited and made specific to a M&R solution. The right-hand column is an estimate of the expected service life of the alternative. Figure A20 displays an example of an alternative selected to fix a problem like a low girder factor of safety.

43. When you select an alternative on the list, it is added to the M&R solution form. You are prompted to enter the Year the alternative would start, edit the Description of the alternative, edit the Exp(ected) Life, and finally enter an estimate of the current Cost to implement the alternative. Once you enter the cost, the program automatically returns to the Problem List window (Figure A17) to allow you to select another alternative to add to the M&R solution. This continues until you are finished selecting alternatives.

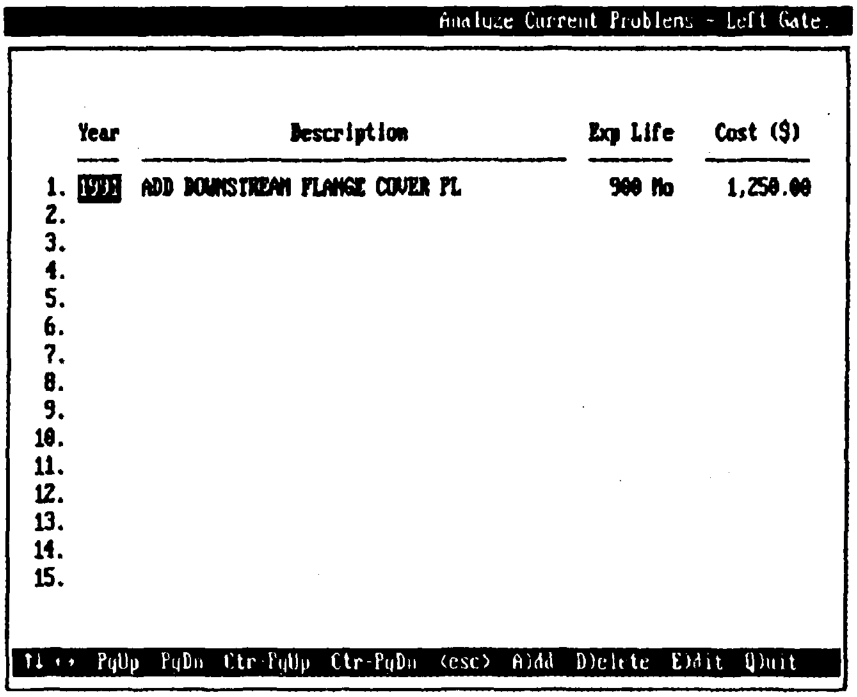

Figure A20. Example of selected M&R alternative

To stop the selection process, select **<esc>** at the Problem List (Figure A17). This returns you to the M&R solution form. Then select **Quit** to exit and save the defined M&R solution.

44. Input of an estimate of the current cost is optional. This information is required to perform a life cycle cost analysis in consequence modeling, but it is not required to evaluate changes in the condition index. You can bypass the cost entry to perform condition index evaluation in consequence modeling and later return and edit the cost estimate into the M&R solution.

Saving an M&R solution

45. When **Quit** is selected, you are prompted to select a solution number and enter a name to describe the M&R solution. Figure A21 illustrates the selection of solution number **1**. The description MINOR REPAIR has been affixed to the M&R solution with two alternatives (displayed behind the window). After saving the M&R solution, you are prompted to Add/Edit another version? (y). You can enter **y** to continue and enter another M&R solution, or enter **n** and return to the Maintenance & Repair Analysis menu. If **y** is selected, the M&R solution form will be displayed and new analysis parameters must be defined for the new M&R solution.

46. You have another choice when beginning to save an M&R solution. Selecting **<esc>** (instead of a number) will let you abandon an M&R solution that has just been created or edited. You are prompted to confirm the intent to discard the data or to back up and save the M&R solution.

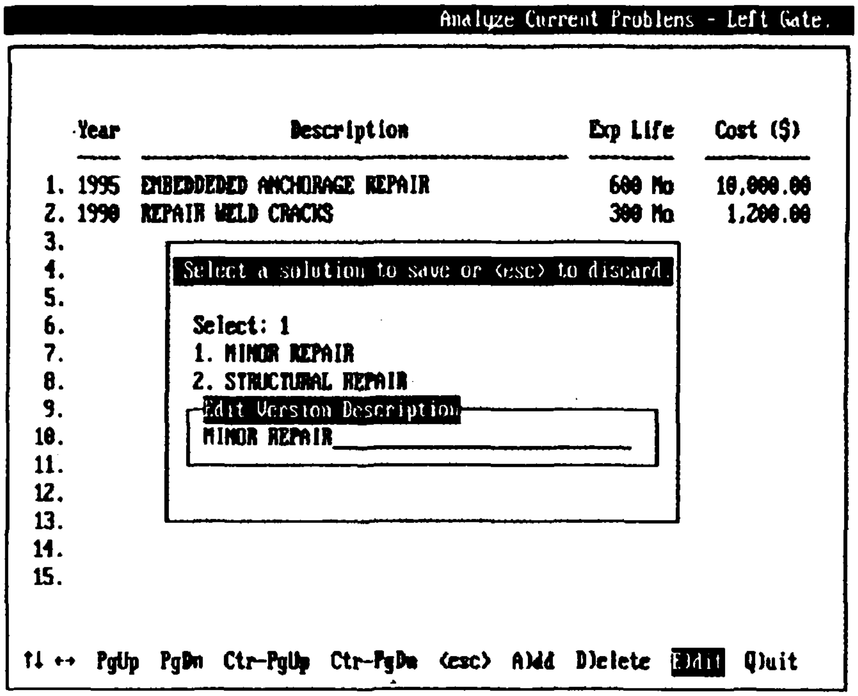

Figure A21. Saving an M&R solution

47. Returning to the Maintenance and Repair Analysis menu, selecting **2 - Review Previously Selected Alternatives**, will display a window (Figure A22) allowing you to select from the list of M&R solutions previously defined and saved to the project structure file. Once you select an M&R solution, the completed M&R solution form and defined parameters will be displayed. You can then edit or add to the M&R solution by changing analysis parameters, selecting additional alternatives, or deleting previously selected alternatives from the list.

Consequence modeling of M&R solutions

48. After at least one M&R solution has been defined and saved, selecting **3 - Consequence Modeling of M&R solutions** initiates a "What if?" scenario in the M&R module. This modeling permits you to correct the problems or deficiencies observed in the inspection or identified by the condition index evaluation. You are is directed to model each of the previously defined M&R solutions to analyze the consequences of the maintenance and repair scenario in two ways:

a. What will be the change in condition index of the structure if the fixes are made? The functional condition index and the structural condition index are each evaluated separately and then combined.

b. What will be the first cost and the annual cost of this M&R solution? Life cycle cost analysis is optional. You must enter costs at the M&R Alternative selection level for this calculation to be executed.

NOTE: Consequence Modeling does not have any effect on the original structure inspection data files or on the actual computed condition index values. The condition index values calculated in this model are stored in a temporary file structure and are not accessed by any routines outside of consequence modeling.

49. Selecting **3 - Consequence Modeling** displays all of the M&R solutions and allows you to make one of these choices.

1 to 5 - Choose one of five M&R solutions for consequence modeling.

6 - Print the M&R solutions - This prints a brief schedule of the alternatives that are components of the M&R solutions. This print selection is also used to get a final print report of the M&R solutions after all the solutions have been modeled and the revised indexes and annual costs have been posted to the data file.

7 - Return to Maintenance & Repair Analysis menu

50. Figure A23 illustrates a typical display of M&R solutions. Each solution displays the Old Combined CI (from MITER evaluation), the New Combined CI, First Cost ($), and Annual Cost ($), if these have been previously computed.

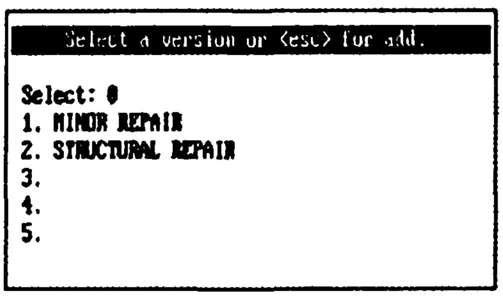

Figure A22. Review list of previously selected alternatives

51. After an M&R Solution is selected, the next screen, Figure A24 displays more detail about the functional and structural condition indexes and lists all of the alternatives attached to the M&R solution. At the bottom of the screen is a menu to allow you to choose condition index modeling, life cycle cost analysis (LCCA), or print reports of the selected M&R solution.

52. The menu choices are these:

1 - Perform functional CI modeling - This calls for you to edit the functional data file to reflect changes that would occur to the functional condition index if this solution were implemented.

2 - Perform structural CI modeling - The structural condition index may also change as a result of the alternatives proposed in the M&R solution being modeled. If the combined condition index is controlled by a low structural CI, then a message is displayed immediately after the calculation of the Functional CI advising you to perform Structural CI modeling.

3 - Perform LCCA modeling - This selection calculates total first cost and annual cost of the proposed M&R solution.

4 - Print consequence modeling report - This selection produces a hard copy of the current M&R solution data. To get a complete printout of the Consequence Model report, perform options **1**, **2**, and **3** before selecting this print. This is the only print call that will produce documentation of the changes made to the functional data, the changes made to structural parameters, and the backup cost data for LCCA in the current M&R solution.

```
                Description Of M&R Solutions

1 MINOR REPAIR
       Old combined CI - 61          New combined CI - Not computed
       First  cost($) - Not computed Annual cost($) - Not computed

2 STRUCTURAL REPAIR
       Old combined CI - 61          New combined CI - Not computed
       First  cost($) - Not computed Annual cost($) - Not computed

3

4

5

6 Print M&R solutions description

7 Return to M&R menu


  Choose M&R Solution to perform consequence modeling
```

Figure A23. Description of M&R solutions

M&R Sol. STRUCTURAL REPAIR

Old funct CI	: 76	New funct CI	: Not computed
Old struc CI	: 61	New struc CI	: Not computed
Old comb. CI	: 61	New comb. CI	: Not computed
Total first cost:	Not computed	Annual cost	: Not computed

Year	Description	Exp Life	Current cost ($)
1991	ADD DOWNSTREAM FLANGE COVER PL	900	1,250.00

1 - Perform functional CI modeling
2 - Perform structural CI modeling
3 - Perform LCCA modeling
4 - Print consequence modeling report
5 - Return to solution select menu
6 - Return to M&R menu

Figure A24. M&R modeling menu

Many of the edited changes in the modeling routines are not recorded to a permanent data file. The temporary data is overwritten the next time a new M&R solution is modeled.

5 - Return to solution select menu - This returns the program to the M&R Solutions menu illustrated in Figure A23.

6 - Return to Maintenance & Repair Analysis menu is illustrated in Figure A14. This is the last menu and user selection point in the consequence modeling module. Choices 1 through 4 will each return to this menu for further selection. This selection exits from consequence modeling.

7 - Return to review previous screen of solution alternatives - This returns (or pages up) to the previous partial window display of M&R alternatives.

NOTE: This choice does not display if only one window is required to display the alternatives.

Functional condition index modeling

53. Selection of **1 - Perform functional CI modeling** displays Figure A25. The functional problems with condition indexes less than 100 for either gate are displayed (Figure A25). Problems with condition indexes of 100 for both gate leaves are omitted. You edit each of the displayed functional distresses by modifying the data corresponding to each distress (Figure A26). The magnitude of the data reduction (if any) should correspond

The following distresses will be displayed for
for review and edit of current inspection conditions.
The remaining distresses already have a calculated
functional CI equal to 100 for both gate leaves

FUNCTIONAL CI : BARKLEY UPR_GATE

Condition Index		Right Gate	Left Gate
ANCHOR SYSTEM	:	60	71
LONG. MOVEMENT	:	74	74
OFFSET CI	:	65	65
GAP CI	:	85	94
CORROSION	:	74	74
DENTS	:	40	100
LEAKS & BOILS	:	70	58
ELEVATION	:	83	69
COMBINED CI	:	70	76

Hit any key to continue

Figure A25. Functional problems

Downstream movement of miter point

The position of the miter point at
the sill has moved downstream 1.304

Adjustments to the gate may change the
downstream movement of the gate and is
not expected to allow movement
downstream of more than : ______

Figure A26. Edit functional distresses

to the alternatives proposed in the M&R solution being modeled. After the last distress is modified, the model recalculates the functional condition index and displays it for review.

54. After you follow screen instructions to continue, the program returns to the M&R Modeling menu (Figure A24). You make another modeling choice 1, 2, or 3; return to the just-completed model to change a parameter; select the **print** option; or return to another menu.

55. Selection of **2 - perform structural CI** will direct the program to edit pages 6 through 9 of the inspection form corresponding to the changes proposed in the M&R solution. The program saves all structural data changes in a temporary file. The original inspection form will remain unchanged. Figure A27 illustrates structural CI modeling.

56. After calculations, an intermediate screen similar to Figure A11 can be reviewed. After following the screen instructions to continue, the program returns to the M&R Modeling menu (Figure A24). You can make another modeling choice 1, 2, or 3; return to the just completed model to change a parameter; select the **print** option; or return to another menu.

Life-cycle cost analysis (LCCA)

57. Selection of **3 - Perform LCCA** will direct the program to the LCCA Parameters window that you can confirm or edit. Figure A28 illustrates the type of data you must provide to perform LCCA. Part VI describes the method for calculating the first cost and annual cost. The first three parameters

Miter Gate Structure: BARKLEY - UPR_GATE

MITER data sheet 8

GIRDER WEB THICKNESSES (in.) — (Fig. 15)

Groups of similar girders: Top girder NGIRDI	Bottom girder NGIRDM	Web end zone thickness GWET	Web center zone thickness GWCT
==> 1	1	.5	.5
==> 2	7	.5	.5
==> 8	9	.625	.625
==> 10	10	.75	.75
==> 11	11	1	1
==> x			

GIRDER FLANGES, UPSTREAM (in.) — (Fig. 15)

Groups of similar girders: Top number NGIRDI	Bottom number NGIRDM	Upstream flange widths: GUFEW	GUF34W	GUF4CW
==> 1	5	9	9	9

AT FIRST CHARACTER SPACE: X)SKIP TO NEXT, Z)DELETE, E)END OF PAGE

Figure A27. Structural modeling

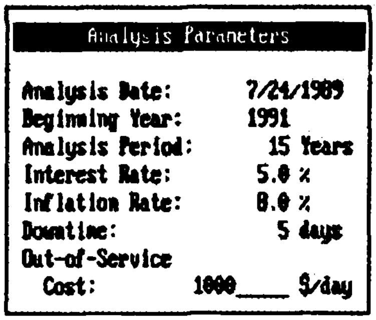

Figure A28. Life-cycle cost parameters

were entered at the beginning of the M&R solution development. They can be changed at this time. The interest rate and inflation rate must be entered at this time. The downtime and out-of-service cost are optional entries. A second window (Figure A29) displays a schedule of intermediate cost data in the computation of first cost and annual cost.

58. Following screen instructions to continue, the program returns to the M&R Modeling menu (Figure A24). The user makes another modeling choice 1, 2, or 3; returns to the just completed model to change a parameter; selects the **print** option; or returns to another menu.

Problem and Alternative Data Base

59. The problem and alternative (PNA) data base is a single large file designed to be a single source file for M&R alternatives selection. The problem list in the problems and alternatives data base is a standard list of problems or safety deficiencies that have been identified and related to miter lock gates. The alternative list in the problems and alternatives data base is a standard list of M&R alternatives that can be applied to a miter lock gate structure.

M&R Sol - STRUCTURAL REPAIR

Old funct CI	: 76	New funct CI	: Not computed
Old struc CI	: 61	New struc CI	: 73
Old comb. CI	: 61	New comb. CI	: 73
Total first cost:	7290	Annual cost	: 1093

Year	Description	Current cost($)	First cost($)	Total cost($)
1991	ADD DOWNSTREAM FLANGE COVER PL	1250	1458	3031
Downtime cost		5000	5832	13367

Hit any key to continue . . .

Figure A29. Life-cycle cost data

Problem list

60. The list of problems for miter lock gates consists of 13 items. You should not change the number of items on the list or the order of the list. The number of occurrences passed to the Problem List (Figure A17) in maintenance and repair analysis is relative to a fixed order of problems in miter lock gate analysis data. The description and order of miter lock gate problems are as follows:

1. Anchorage movement
2. Elevation change
3. Miter offset
4. Gaps
5. Downstream movement
6. Cracks
7. Leaks and boils
8. Dents
9. Noise, jumping, or vibration
10. Corrosion
11. Low girder factor of safety
12. Low skin factor of safety
13. Low intercostal factor of safety

61. The first 10 problems correlate to the 10 distresses that are identified on pages 1 through 5 of the inspection form. The last three problems correlate structural deficiencies identified in the calculation of the structural condition index. The condition indexes for all 13 problems are listed in the Problem List.

62. Each project problem list is unique to the particular miter lock gate structure. The uniqueness of the list is defined by the identified distresses and structural deficiencies from the inspection data files for the particular miter lock gate structure.

Maintenance and repair alternatives

63. The list of M&R alternatives is the part of the problems and alternatives data base that is designed to be updated by you. The program is distributed with a short list of M&R Alternatives that can be used to formulate M&R solutions. However, the real intent of the list is for you to add to the list of M&R Alternatives from personal experience with successful projects or new technology and product solutions. You can make the problems and alternatives data base a personal resource of information about maintenance and repair alternatives.

Update problem or alternative data base

64. Selecting **4 - Update Prob/Alt Database** from the Maintenance and Repair Analysis menu (Figure A14) calls up a program routine to allow you to edit or add to the initial M&R Alternatives data base. The initial screen display lists the structure types that are included in the data base. For this distribution, steel sheet pile (SSP) and miter lock gate (MITER) are included. See Figure A30. Selecting **1 - MITER** proceeds to the next option. Selecting **<esc>** returns to the Maintenance & Repair Analysis menu.

65. Continuing to the next screen, Figure A31, allows you several options to edit structure data. They are displayed at the bottom of the screen.

a. **Change** by typing **C** allows editing of the description of the structure type. Do not change the structure type MITER or SSP because the M&R solutions are keyed to the description term of each. Adding new structure types will not affect MITER or SSP, nor will MITER or SSP be able to access data in any other structure type.

b. **Delete** by typing **D** allows deleting a structure type. Do not use on MITER or SSP.

c. **Edit Problems** by typing **P** displays the list of problems identified ith SSP. Do not change the order of the first 13 problems. This will cause erroneous reporting of problem occurrences. NOTE: It is possible for you to add undefined problems to the end of the list and tag M&R Alternatives to the problem. However, these added problems will never report a condition index out of the inspection data file. You can use this for defining very specific problems for a MITER or SSP structure.

EDIT STRUCTURE DATA

LIST OF STRUCTURE TYPE

1 FILTER
2 SSP

Choose struct type or Esc

Figure A30. Select structure type

EDIT STRUCTURE DATA

LIST OF STRUCTURE TYPE

1 FILTER
2 SSP

OPTIONS: (C)hange, (D)elete, Edit (P)roblems, Edit (A)lternatives, Esc

Figure A31. Edit Structure Data

d. **Edit Alternatives** by typing **A** displays the list of maintenance alternatives identified with MITER or SSP. This will be the primary selection of the user to change, update, and improve the M&R Alternatives list.

Edit problems

66. Selecting **Edit Problems** by typing **P** displays the screen shown in Figure A32. The option keys at the bottom of the screen do the following:

a. **Add** will insert a row at the location of the cursor to create a new problem description. You will be prompted to enter a note to further describe the problem. (See Figure A33.) This is the same note you can view in M&R solution development when viewing a note attached to a problem.

b. **Change** will edit the description of the problem and also the note attached to the problem.

c. **Delete** will delete a problem from the list.

d. **Print** will generate a printout of the problem list.

e. **View alternatives** will display a window, Alternatives for this problem. Selecting the alternative that is highlighted will display a note window describing the alternative. (See Figure A34.)

f. **<esc>** will return to the initial structure type selection.

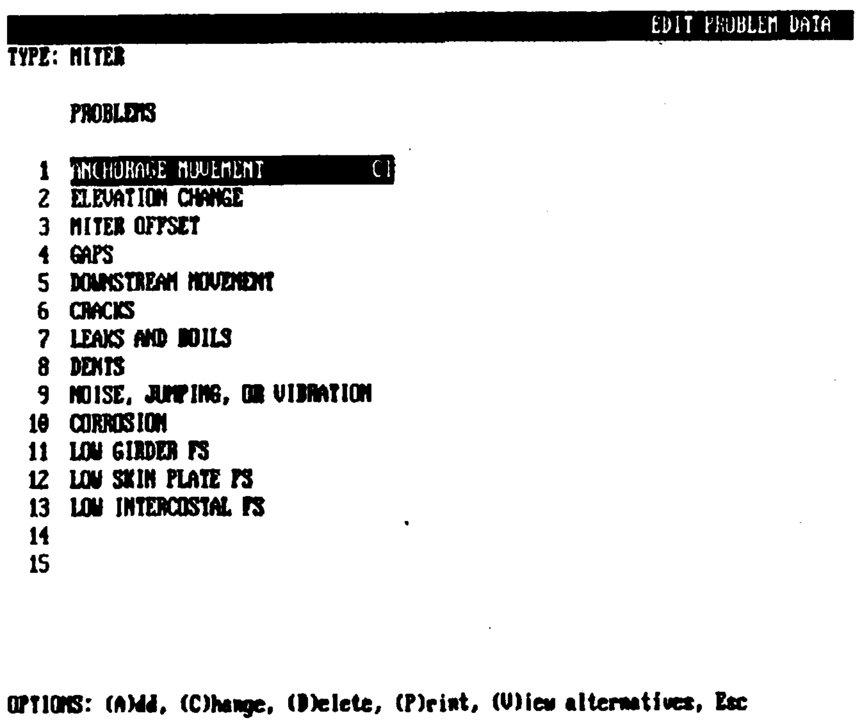

Figure A32. Problem list

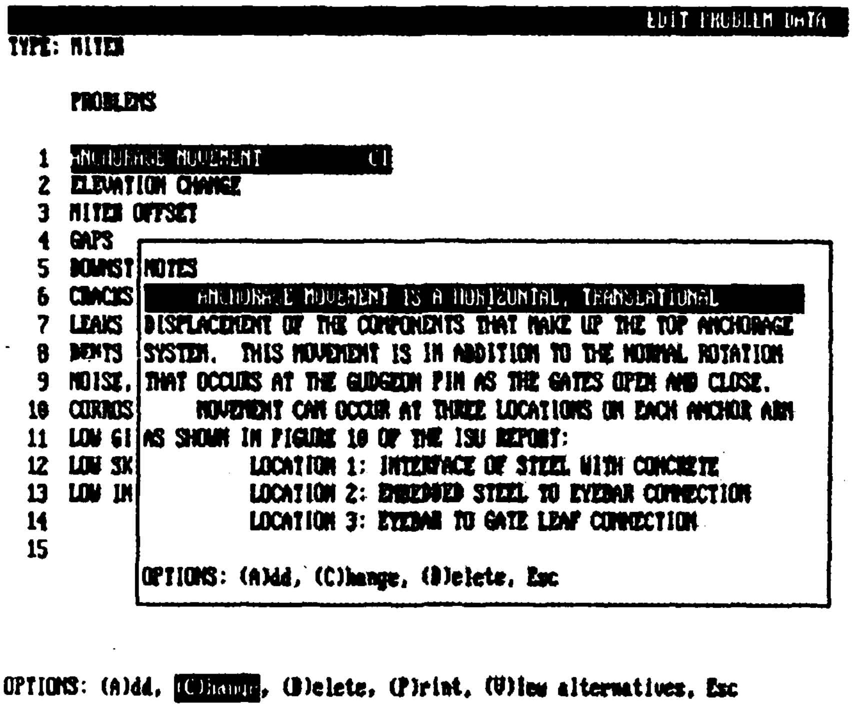

Figure A33. Problem notes

Edit alternatives

67. Returning to Edit Structure Data (Figure A31) and selecting **Edit Alternatives** by typing **A** displays the following screen, Maintenance Alternatives. The option keys at the bottom of the screen do the following:

a. **Add** will insert a row at the location of the cursor to create a new alternative description. You will be prompted to enter the **Expected Life** of the alternative. You are asked to identify problems this alternative can solve by adding them to a list (see Figure A35). You will be prompted to enter a note to further describe the alternative. This is the same note you can view in M&R solution development when viewing a note attached to an alternative.

b. **Change** will edit the description of the alternative, the expected life, the attached problem list, and also the note attached to the alternative.

c. **Delete** will delete an alternative from the list.

d. **Print** will generate a printout of the alternative list.

e. **View problems** will display a window, Possible problems list (Figure A36). Selecting the problem that is highlighted will display a note window listing the problems solved by this alternative. (See Figure A37.)

f. **<esc>** will return to the initial structure type selection.

```
                                                  EDIT PROBLEM DATA
TYPE: MITER

     PROBLEMS                              ALTERNATIVES FOR THIS PROBLEM

  1  ANCHORAGE MOVEMENT          C        1.EMBEDDEDED ANCHORAGE REPAIR
  2  ELEVATION CHANGE                     2.EYE BAR CONNECTION REPAIR
  3  MITER OFFSET                         3.GUDGEON PIN/BUSHING REPAIR
  4  GAPS
  5  DOWNSTREAM MOVEMENT
  6  CRACKS
  7  LEAKS AND BOILS
  8  DENTS
  9  NOISE, JUMPING, OR VIBRATION
 10  CORROSION
 11  LOW GIRDER FS
 12  LOW SKIN PLATE FS
 13  LOW INTERCOSTAL FS
 14
 15
                                          Choose alternative or Esc

OPTIONS: (A)dd, (C)hange, (D)elete, (P)rint, (V)iew alternatives, Esc
```

Figure A34. Alternatives for this problem

```
                                                EDIT ALTERNATIVE DATA
TYPE: MITER

     MAINTENANCE ALTERNATIVES

  1  EMBEDDEDED ANCHORAGE REPAIR
  2  EYE BAR CONNECTION REPAIR
  3  GUDGEON PIN/BUSHING REPAIR
  4  QUOIN BEARING MATERIAL REPAIR
  5  FLOATING PINTLE REPAIR
  6  PINTLE WEAR
  7  ADJUSTMENT OF DIAGONALS
  8  GATE ADJUSTMENT
  9  MITERING DEVICE ADJUSTMENT
 10  ADJUST CLOSURE TIMING
 11  ADJUST GATE
 12  REPAIR QUOIN/BEARING SURFACE
 13  ADJUST GATE SEALS
 14  PINTLE REPAIR
 15  FIXED PINTLE REPAIR

OPTIONS: (A)dd, (C)hange, (D)elete, (P)rint, (V)iew Prob, Esc
```

Figure A35. Edit alternative data

```
ALTERNATIVE: EMBEDDEDED ANCHORAGE REPAIR

    PROBLEMS FOR THIS ALTERNATIVE          POSSIBLE PROBLEM LIST

 1  ANCHORAGE MOVEMENT            CI       1. ANCHORAGE MOVEMENT          CI
 2                                         2. ELEVATION CHANGE
 3                                         3. MITER OFFSET
 4                                         4. GAPS
 5                                         5. DOWNSTREAM MOVEMENT
 6                                         6. CRACKS
 7                                         7. LEAKS AND BOILS
 8                                         8. DENTS
 9                                         9. NOISE, JUMPING, OR VIBRATION
10                                        10. CORROSION
11                                        11. LOW GIRDER FS
12                                        12. LOW SKIN PLATE FS
13                                        13. LOW INTERCOSTAL FS
14
15

                                           ESC to quit or select Problem
OPTIONS: (A)dd, (D)elete, (E)dit problem list, (P)rint, Esc
```

Figure A36. Add problem to alternative list

```
                                                   EDIT ALTERNATIVE DATA
TYPE: MITER

    MAINTENANCE ALTERNATIVES                  PROBLEM LIST

 1  EMBEDDEDED ANCHORAGE REPAIR               LEAKS AND BOILS
 2  EYE BAR CONNECTION REPAIR                 DOWNSTREAM MOVEMENT
 3  GUDGEON PIN/BUSHING REPAIR                ELEVATION CHANGE
 4  QUOIN BEARING MATERIAL REPAIR
 5  FLOATING PINTLE REPAIR
 6  PINTLE WEAR
 7  ADJUSTMENT OF DIAGONALS
 8  GATE ADJUSTMENT
 9  MITERING DEVICE ADJUSTMENT
10  ADJUST CLOSURE TIMING
11  ADJUST GATE
12  REPAIR QUOIN/BEARING SURFACE
13  ADJUST GATE SEALS
14  PINTLE REPAIR
15  FIXED PINTLE REPAIR

OPTIONS: (A)dd, (C)hange, (D)elete, (P)rint, (V)iew Prob, Esc
```

Figure A37. Problem solved by M&R alternative

APPENDIX B: SAMPLE REPORTS

1. The following figures illustrate the report output available from MITER.

2. Inspection Report (Figure B1) - output file of data that corresponds to the inspection forms pages 1 through 9.

3. Summary Report (Figure B2) - summary data of the structure condition index and detail about the functional and structural condition indices. The sample summary report bound herein is in substance the same report included in the previously published User's Manual by Greimann and Stecker (1987). There is a slight variation in the structural condition index value because the girders have been modeled slightly different in the later case.

4. Description of M&R Solutions Report (Figure B3) - summary output of the defined M&R solutions and a listing of the selected alternatives for each solution. Also lists the status of condition indices and costs for each M&R solution.

5. Consequence Modeling Report (Figure B4) - detail output for a specific M&R solution that includes data on life cycle cost of each alternative, the status of condition indices, and finally the backup parameters and temporary changes made to data files to generate the results in the current model.

6. Deterioration curve (Figure B5) - graph of condition index verses time.

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 1

NAME OF CIVIL WORKS PROJECT:

(1): BARKLEY LOCK & DAM

(2): UPPER GATE

LOCATION OF CIVIL WORKS PROJECT:

(1): BARKLEY GATE

(2): GRAND RIVER, KY.

DATE OF INSPECTION : 10/25/88

INSPECTED BY : GREIMANN, STECKER, RENS

GATE ID:
1. Upper Gate
2. Lower Gate
GATE ID (no.) : 1

TYPE OF FRAMING PRESENT:
1. Horizontal
2. Vertical
STRUCTURE TYPE(no.) : 1

TYPE OF PINTLE:
1. Fixed
2. Floating
PINTLE SYSTEM(no.) : 1

TYPE OF SKIN PLATE:
1. Single
2. Double
SKIN TYPE(no.) : 1

LENGTH OF LOCK CHAMBER(ft) : 800
WIDTH OF LOCK CHAMBER(ft) : 110
HEIGHT OF GATE LEAF(ft) : 50
GATE WIDTH : 61.75

POOL LEVELS	UPPER POOL(ft)	LOWER POOL(ft)
PRESENT POOL WATER LEVELS	: 357.1	303.3
RECORD LOW WATER LEVEL	: 354	300
RECORD HIGH WATER LEVEL	: 370.8	347.3

DO YOU ROUTINELY DEWATER THE LOCK CHAMBER (*Y/N) :YES
*IF YES, WHAT YEAR WAS THE LOCK LAST DEWATERED? : 1983
* INTERVAL PERIOD : 5

CONSTRUCTION DATE : 1966

Figure B1. Inspection report (Sheet 1 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 2

ARE THE ORIGINAL GATE LEAVES CURRENTLY IN PLACE (*Y/N)? y

*If not, identify current gate leaf history:
==>

ARE DRAWINGS AVAILABLE FOR GATE LEAVES IN PLACE (Y/N)? y

ARE THE DRAWINGS INCLUDED WITH THIS FILE (Y/N)? n

PAST 10 YEAR HISTORY OF:
=======================

MAJOR MAINTENANCE, REPAIRS, OR OTHER MODIFICATIONS.
Date   Description ('X' to stop, 'Z' to delete current line)
==>

==> c

PREVIOUS INSPECTION OR REVIEWS.
Date   Description ('X' to stop, 'Z' to delete current line)
==>

TYPE OF FENDER PROTECTION AND CONDITION OF FENDERS:
('X' to stop, 'Z' to delete current line)
==> DENT IN STEEL FENDER

TYPE OF WALKWAY ON GATE LEAF AND CONDITION OF WALKWAY:
('X' to stop, 'Z' to delete current line)
==>

OTHER COMMENTS
('X' to stop, 'Z' to delete current line)
==>

Figure B1. (Sheet 2 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 3

FACING DOWNSTREAM AT UPPER GATE, IDENTIFY LEAF AS LAND OR RIVER SIDE

LEFT GATE LEAF = LAND
RIGHT GATE LEAF = RIVER

OPENING AND CLOSING OF GATE LEAVES

	Left Gate(RG) (Y/N)	Closed 25 50 75 100	Right Gate(LG) (Y/N)	Closed 25 50 75 100
DO THE DIAGONALS FLAP?	Y	0	Y	0
DOES THE GATE JUMP?	N	-	N	-
IS THERE GATE NOISE?	n	-	N	-
DOES THE GATE VIBERATE?:	N	-	N	-

ELEVATIONS OF GATE LEAF

Left leaf	Recessed	Near Miter	Miter 1' head	Miter Full head
Quoin	: 4.46	4.47	4.47	4.47
Miter	: 4.51	4.54	4.55	4.53
Right leaf				
Quoin	: 4.46	4.47	4.47	4.48
Miter	: 4.53	4.56	4.55	4.54

ANCHORAGE SYSTEM MEASUREMENT

Is the Concrete Cracked or Spalled at Location 1?

	Left gate	Right gate
Parallel(Y/N)	: N	Y
Perpendicular(Y/N)	: Y	Y

Left gate Arm Dim.(in)	Recessed	Near Miter	Miter 1' head	Miter Full head
Parallel 1	: 0.438	0.438	0.440	.441
Parallel 2	: 43.125	43.125	43.125	43.125
Parallel 3	: 12.875	12.813	12.813	12.813
Perpendicular 1	: 0.324	0.319	0.318	0.320
Perpendicular 2	: 24.5	24.563	24.563	24.5
Perpendicular 3	: 18.563	18.563	18.563	18.563

Right gate Arm Dim.(in)	Recessed	Near Miter	Miter 1' head	Miter Full head
Parallel 1	: 0.345	0.347	0.348	0.349
Parallel 2	: 43.375	43.375	43.375	43.313
Parallel 3	: 12.625	12.563	12.563	12.5
Perpendicular 1	: 0.193	0.193	0.194	0.199
Perpendicular 2	: 20.25	20.25	20.25	20.156
Perpendicular 3	: 21.75	21.813	21.875	21.875

Figure B1. (Sheet 3 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 4

OFFSET OF MITER BLOCKS WITH GATES AT MITER (1'HEAD),

Location	Measurement(in)	Walkway distance(ft)	Gate downstream
Top	: .25	3.75	L
DSWL	: 0	24	L

DSWL : Down stream water level

GAP BETWEEN BEARING BLOCKS AT MITER (1'HEAD)

Location	Measurement(in)	Walkway Distance
Left quoin @ Top	: 0	6
Left quoin @ DSWL	: .0157	26
Right quoin @ Top	: 0	6
Right quoin @ DSWL	: .0396	26
Miter @ Top	: 0	3.75
Miter @ DSWL	: 0	26

LONGITUDNAL POSITION OF MITER POINT

	Measurement (in)		
Location	1'head	Full head	Walkway distance(ft)
Top	: 4.875	4.5	3
DSWL	: .875	1.25	24

LOCK CHAMBER FILLING (OR EMPTYING)

Does the gate vibrate?

Left gate(Y/N) : Y

Right gate(Y/N) : Y

DOES A LEAK FOLLOW THE RISING (OR EMPTYING) WATER LEVEL AND THEN CLOSE AS THE WATER CONTINUES TO RISE (EMPTY)?

Left Quoin (Y/N) : N

Miter (Y/N) : N

Right Quoin (Y/N) : N

DOES THE GAP BETWEEN MITER BLOCKS CHANGE?

(Y/N) : Y

If yes, select from the following choices the most accurate description of the change.

1. Top gap initially open but closes under full head.
2. Top gap opens wider but closes under full head.
3. Top gap opens and remains open.
4. Top of miter is closed but gap opens between water line and top.
5. Top of miter is closed and gap between water line and top closes.

Choice No. : 4

Estimate the maximum width of gap (in) : .3

Estimate the location of the maximum gap from the walkway (ft) : 14

Figure B1. (Sheet 4 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 5

OBSERVATIONS FROM BOAT

CORROSION AT SPLASH ZONE (LEVEL 0,1,2,3,4, OR, 5)

	Left Gate(LG)		Right Gate(RG)	
	Up Stream	Down Stream	Up Stream	Down Stream
Skin	:1	1	1	1
Girder	:1	1	1	1
Intercostal	:1	1	1	1

DENTS -- SKIN PLATE(S), GIRDERS(G), OR INTERCOSTALS(I)

Gate	Component	Location, Distance From:		Size (ft)	
RG or LG	S, G, or I	Walkway (ft)	Quoin (ft)	Height	Width
==> RG	G	15	58	1	.5
==> x					

CRACKS -- SKIN PLATE(S), GIRDERS(G), OR INTERCOSTAL(I)

Gate	Component	Location, Distance From:		Size (ft)
RG or LG	S, G, or I	Walkway (ft)	Quoin (ft)	Length
==> x				

BEARING BLOCK LEAKS @ LEFT (L), MITER (M), or RIGHT (R)

Type R,M,L	Distance From Walkway(ft)	Length(ft)
==> R	40	.5
==> M	28	.25
==> x		
==> M	61	
==> L	40	

SKIN LEAKS @ LEFT (L) OR RIGHT (R)

Gate	Type	Shortest Distance From :		
R or L	Hor(H) or Vert(V)	Walkway(ft)	Quoin(ft)	Length
==> x				

BOILS @ LEFT (L), RIGHT (R) OR MITER (M)

Type (R,L or M)	Distance from Quoin(ft)
==> M	61
==> L	40
==> x	

Figure B1. (Sheet 5 of 9)

MITER data sheet 6

CALCULATION DATE :10/25/88

CALCULATED BY : RENS

REQUIRED OVERALL GEOMETRY -- (Fig. 13)

Positive elevation of sill above any datum, ELSILL (ft): 333.0
Sill to bottom of skin plate, GBOT (ft): 0.75
Sill to overflow elevation at top of gate, GTOP (ft): 44.75

REQUIRED OVERALL LEAF GEOMETRY -- (Fig. 13)

Leaf between contact points, GLENG (ft): 62.0
Gate leaf slope, GSLOPE: 3
Working line to downstream edge of girder webs,
GWORKL (ft): .313
Quoin contact point to gudgeon pin, GQUOIN (ft): 1.98
Working line to gudgeon pin (positive when contact point is
downstream from gudgeon), GPIN1 (ft): 1.25

COMMON GIRDER GEOMETRY DIMENSIONS -- (Fig. 13)

Girder web depth, GWEBD (in.): 82
Quoin contact point to center of nearest end diaphragm along
working line, DQPED (in.): 117.25
Center of end diaphragm at miter end of gate to miter
contact point along working line, DEDMP (in.): 117.25
Bottom girder downstream flange extension below
web centerline, BGDFD (in.): 3

GIRDER ELEVATIONS -- (Fig. 13)

Number of girders in the gate leaf, NGIRDS: 11

Girder Number, NGIRD	Vertical Distance above sill, VD(ft):
==> 1	44.75
==> 2	40.75
==> 3	36.25
==> 4	31.75
==> 5	27.25
==> 6	22.75
==> 7	18.25
==> 8	13.75
==> 9	9.25
==> 10	5.25
==> 11	.75
==> x	

Figure B1. (Sheet 6 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 7

GIRDER DIAPHRAGM SPACING -- (Fig. 13)

	Top girder of similar pnl	Bottom girder of similar pnl	Space between end diaphragms	Intercostal spaces between adjacent diaphragms
	NPANLI	NPANLN	NDS	NIS
==>	1	10	4	6
==>	10	11	8	3
==>	x			

DEAD AND LIVE LOADS:

Additional dead load, including ice, mud, walkway, gusset plates, etc, ADEAD (lbs): 6642
Quoin contact point to centroid of ADEAD along working line, XDEAD (ft): 31.0
Downstream edge of girder web to centroid of ADEAD, ZDEAD (in.): 0
Buoyancy force of acting on dry weight of gate, ABUOY (lbs.): 0
Quoin contact point to centroid of ABUOY along working line, XBUOY (ft): 0
Downstream edge of girder web to centroid of ABUOY, ZBUOY (in.): 0
Applied live load, including walkway and bridgeway, ALIVE (lbs): 0

REQUIRED WATER ELEVATIONS -- (FEET ABOVE ELSILL) :

Elevation of upper pool, ELUP (ft): 375.0
Elevation of lower pool, ELLP (ft): 302.0
Full submergence elevation, ELFS (ft): 378.125
Operating water elevation, ELOW (ft): 375

STEEL YIELD STRENGTH (KSI):

Misc.	Webs	Flanges	Skin
==>36	36	36	36
Stiffeners	Intercostals	Quoin	Diaphragms
==>36	36	36	36

Figure B1. (Sheet 7 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

MITER data sheet 8

GIRDER WEB THICKNESSES (in.) -- (Fig. 15)

Groups of similar girders Top girder NGIRDI	Bottom girder NGIRDN	Web end zone thickness GWET	Web center zone thickness GWCT
==> 1	1	.5	.5
==> 2	7	.5	.5
==> 8	9	.625	.625
==> 10	10	.75	.75
==> 11	11	1	1
==> x			

GIRDER FLANGES, UPSTREAM (in.) -- (Fig. 15)

Groups of similar girders Top number NGIRDI	Bottom number NGIRDN	Upstream flange widths GUFEW	GUF34W	GUF4CW
==> 1	5	9	9	9
==> 6	6	10.5	10.5	10.5
==> 7	7	12	12	12
==> 8	8	12	12	12
==> 9	10	15	15	15
==> 11	11	16	16	16
==> x				

Upstream flange thickness GUFET	GUFCT	Upstream flange cover plate Dist from quoin GUCPX	Width GUCPW	Thickness GUCPT
==>1	1	0	0	0
==>1	1	0	0	0
==>1	1	0	0	0
==>1.25	1.25	0	0	0
==>1.25	1.25	0	0	0
==>2	2	0	0	0
==>x				

GIRDER FLANGES, DOWNSTREAM (in.) -- (Fig. 15)

Groups of similar girders Top number NGIRDI	Bottom number NGIRDN	Downstream flange widths GDFEW	GDFCW
==> 1	1	9	9
==> 2	5	9	9
==> 6	6	9.5	9
==> 7	7	10.1	9
==> 8	8	9.5	9
==> 9	10	10.1	9
==> 11	11	10.4	12
==> x			

Downstream flange thickness GDFET	GDFCT	Downstream flange cover plate Dist from quoin GDCPX	Width GDCPW	Thickness GDCPT
==>.75	.75	0	0	0
==>.75	.75	0	0	0
==>.75	.75	0	0	0
==>.75	.75	0	0	0
==>1	1	0	0	0
==>1	1	0	0	0
==>1	1	0	0	0
==>x				

Figure B1. (Sheet 8 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE Sun Jul 23 1989

MITER data sheet 9

GIRDER FLANGE COORDINATES (ft) -- (Fig. 15)

Group of similar girders		Splice plate distance from quoin	
Top number	Bottom number	Upstream	Downstream
NGIRDI	NGIRDN	GUFX4	GDFX5
==>1	11	117.25	144
==>x			

GIRDER WEB STIFFENERS (in.) -- (Fig. 15)

Group of similar girders		Number of trans.	Number of long
Top number	Bottom number	stiffener spaces	stiffener pairs
NGIRDI	NGIRDN	NGWTS	NGLS
==> 1	1	0	1
==> 2	9	2	1
==> 10	10	1	1
==> 11	11	0	1
==> x			

Longitudinal stiffener geometry

Stiffener number 1	Width thickness		Stiffener number 2	Width thickness	
GLS1D	GLS1W	GLS1T	GLS2D	GLS2W	GLS2T
==>41	-4	.5	0	0	0
==>41	-4	.5	0	0	0
==>41	-5.5	.5	0	0	0
==>41	-5.5	.5	0	0	0
==>x					

Stiffener number 3	Width thickness	
GLS3D	GLS3W	GLS3T
==> 0	0	0
==> 0	0	0
==> 0	0	0
==> 0	0	0
==> x		

INTERCOSTAL AND SKIN PLATE GEOMETRY (in.) -- (Fig. 15)

Group of similar intercostals		
Top girder number	Bottom girder number	Skin plate thickness
NPANLI	NPANLN	SPT
==> 1	6	.375
==> 7	11	.5
==> x		

Depth (perp to skin)	Stem thickness	Flange Width	Flange Thickness
ODI	STEMT	FWI	FTI
==> 6	.5	0	0
==> 7	.5	0	0
==> x			

Figure B1. (Sheet 9 of 9)

Miter Gate Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

SUMMARY REPORT
=============

PROJECT NAME:
BARKLEY LOCK & DAM
UPPER GATE

LOCATION:
BARKLEY GATE
GRAND RIVER, KY.

INSPECTION DATE: 10/25/88

INSPECTED BY: GREIMANN, STECKER, RENS

The overall functional and structural safety condition has been analyzed and compiled in the following INDICES :

FUNCTIONAL CONDITION INDEX:
Right Gate : 70
Left Gate : 76

CORROSION MODIFIED STRUCTURAL CONDITION INDEX:
Right Gate : 61
Left Gate : 61

COMBINED CONDITION INDEX:
Right Gate : 61
Left Gate : 61

FUNCTIONAL CI

Condition Index		Right Gate	Left Gate
ANCHOR SYSTEM	:	60	71
LONG. MOVEMENT	:	74	74
NOISE JUMP	:	100	100
OFFSET CI	:	65	65
GAP CI	:	85	94
CORROSION	:	74	74
DENTS	:	40	100
CRACKS	:	100	100
LEAKS & BOILS	:	70	58
ELEVATION	:	83	69
COMBINED CI	:	70	76

STRUCTURAL CI

LC	INTERCOSTAL	PNL #	SKIN	PNL #	GIRDER	GRDR #	MINIMUM
1	100.	10	100.	6	83.	7	83.
2	100.	10	100.	6	100.	7	100.
3	100.	2	100.	2	100.	2	100.
4	100.	2	100.	1	100.	2	100.
6	100.	10	100.	6	100.	7	100.
					STRUCTURAL CI		83.

CORROSION MODIFIED STRUCTURAL CI -- RIGHT GATE

INTERCOSTAL	SKIN	GIRDER	MINIMUM
100	100	61	61

CORROSION MODIFIED STRUCTURAL CI -- LEFT GATE

INTERCOSTAL	SKIN	GIRDER	MINIMUM
100	100	61	61

Figure B2. Summary report

Miter Lock Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

DESCRIPTION OF M&R SOLUTIONS

PROJECT NAME:
BARKLEY LOCK & DAM
LEFT UPPER GATE

LOCATION:
BARKLEY GATE
GRAND RIVER, KY.

M&R Solutions and Alternatives:

M&R SOLUTION - MINOR REPAIR

Year	Description	Exp Life	Current cost ($)
1995	EMBEDDED ANCHORAGE REPAIR	600	10,000.00
1990	REPAIR WELD CRACKS	300	1,200.00

Old Functional CI	= 76
New Functional CI	= Not computed
Old Structural CI	= 61
New Structural CI	= Not computed
Old Combined CI	= 61
New Combined CI	= Not computed
Total first Cost ($)	= Not computed
Annual Cost ($)	= Not computed

M&R SOLUTION - STRUCTURAL REPAIR

Year	Description	Exp Life	Current cost ($)
1991	ADD DOWNSTREAM FLANGE COVER PL	900	1,250.00

Old Functional CI	= 76
New Functional CI	= Not computed
Old Structural CI	= 61
New Structural CI	= Not computed
Old Combined CI	= 61
New Combined CI	= Not computed
Total first Cost ($)	= Not computed
Annual Cost ($)	= Not computed

Figure B3. Description of M&R solutions report

Miter Lock Structure: BARKLEY - UPR_GATE   Sun Jul 23 1989

CONSEQUENCE MODELING REPORT

==========================

PROJECT NAME:
BARKLEY LOCK & DAM
LEFT UPPER GATE

LOCATION:
BARKLEY GATE
GRAND RIVER, KY.

M&R SOLUTION - STRUCTURAL REPAIR

Year	Description	Current cost($)	First cost($)	Total cost($)
1991	ADD DOWNSTREAM FLANGE COVER PL	1250	1378	4372

Old Functional CI	= 76
New Functional CI	= Not computed
Old Structural CI	= 61
New Structural CI	= 73
Old Combined CI	= 61
New Combined CI	= 73
Total first Cost ($)	= 6891
Annual Cost ($)	= 1651

LCCA PARAMETERS

Begining Year	= 1991
Period of Analysis (years)	= 15
Inflation Rate(%)	= 5.00
Interest Rate(%)	= 8.00
Down Time (days)	= 5
Out Of Service Cost ($ per day)	= 1,000.00

Figure B4. Consequence modeling report

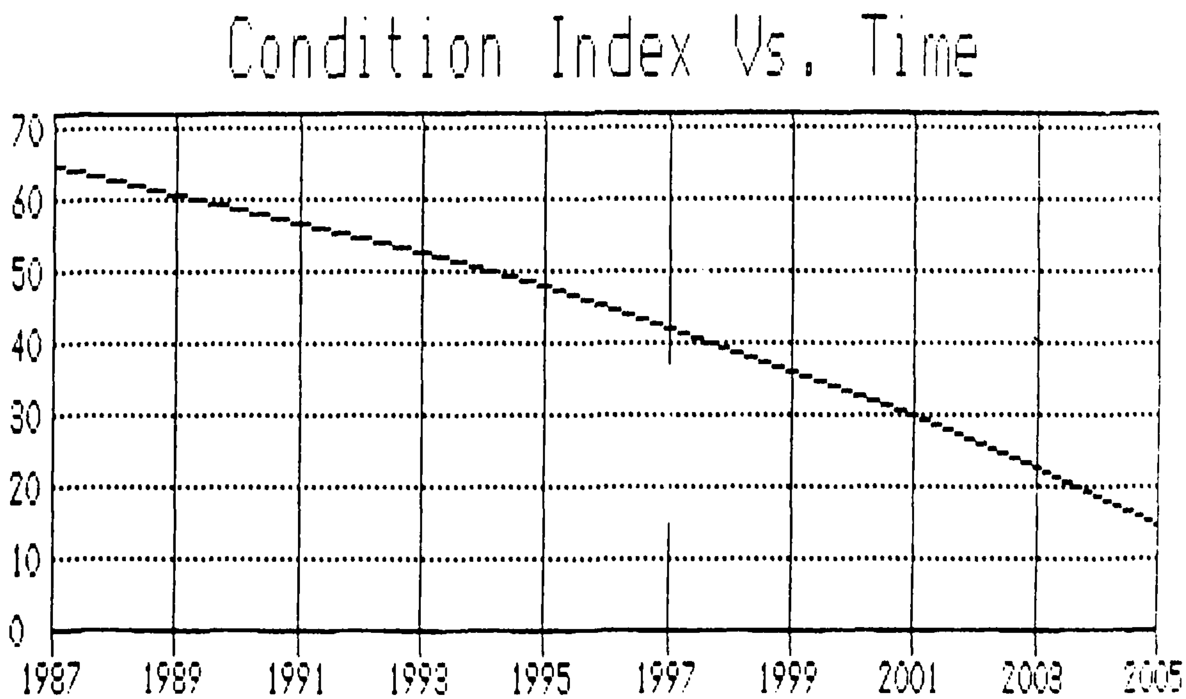

Figure B5. Deterioration curve

ABUOY	= Concentrated buoyancy force acting on dry weight of gate
ADEAD	= Concentrated additional dead load (in addition to girders, skin, intercostals, etc.) ice, mud, gusset plates, etc.
ALIVE	= Concentrated live load including walkway and bridgeway
AP	= Length of analysis period in years
b	= Effective width of skin plate
BF	= Girder bending factor
BF_j	= Bending factor for component j
BGDFD	= Bottom girder downstream flange downward extension below web centerline
C_D	= Initial downtime costs
CI	= Condition Index (structural or functional)
CI(t)	= Condition index in year t
CI_1	= Anchorage system condition index, dimension 1
CI_2	= Anchorage system condition index, dimension 2
CI_3	= Anchorage system condition index, dimension 3
CI_A	= Angular offset condition index
CI_B	= Boil condition index
CI_C	= Contact offset condition index
CI_G	= Girder condition index (cracks, dents, or corrosion)
CI_{Gi}	= Girder condition index, load case i
CI_{Gj}	= Condition index for girder j
CI_i	= Leaf structural condition index, load case i
CI_I	= Intercostal condition index (cracks, dents, or corrosion)
CI_{Ii}	= Intercostal condition index, load case i
CI_{Ij}	= Condition index for intercostal j
CI_M	= Miter condition index (elevation change or gaps)
CI_{para}	= Anchorage system condition index, parallel arm
CI_{perp}	= Anchorage system condition index, perpendicular arm
CI_Q	= Quoin condition index (elevation change or gaps)
CI_{QM}	= Quoin and miter condition index, leaks
CI_S	= Skin condition index (cracks, dents, or corrosion)
CI_{Si}	= Skin panel condition index, load case i
CI_{Sj}	= Condition index for skin panel j
C_m	= 0.85
C_{RM}	= Initial cost of solution
C_{TD}	= Initial downtime costs incremented by the interest rate
C_{TRM}	= Total cost of solution
DEDMP	= Distance along the gate leaf work line from the miter contact point to the end diaphragm
DQPED	= Distance along the gate leaf work line from the quoin contact point to end diaphragm
DSWL	= Down stream water level
ELFS	= Full submergence elevation (same datum as ELSILL)
ELLP	= Lower pool elevation (same datum as ELSILL)
ELOW	= Operating water elevation (same datum as ELSILL)
ELSILL	= Positive elevation of the sill above any datum
ELUP	= Upper pool elevation (same datum as ELSILL)

f	= Huber-von Mises effective stress
F'_e	= Euler stress
f_a	= Working axial steel stress
F_a	= Allowable axial strength
f_b	= Working bending stress
F_b	= Allowable bending strength
FS	= Factor of safety
FS_d	= Design factor of safety
FS_j	= Factor of safety for component j
FTI	= Thickness of parallel intercostal leg
FWI	= Width of parallel intercostal leg
f_x	= Stress perpendicular to f_y (for example, girder flange stress is perpendicular to skin plate stress)
f_y	= Stress perpendicular to f_x (for example, intercostal stress is perpendicular to skin plate stress)
F_y	= Steel yield strength
G	= Girder
GBOT	= Distance between sill and bottom of gate
GDCPT	= Downstream flange cover plate thickness
GDCPW	= Downstream flange cover plate width
GDCPX	= Distance from quoin to downstream flange cover plate
GDFCT	= Downstream flange thickness from splice point
GDFCW	= Downstream flange width from splice point
GDFET	= Downstream flange end zone to splice point thickness
GDFEW	= Downstream flange end zone to splice point width
GDFX5	= Distance from quoin to downstream flange splice point
GLENG	= Length of leaf between contact points
GLS1D	= Longitudinal web stiffener distance from downstream web edge
GLS1T	= Longitudinal web stiffener thickness
GLS1W	= Longitudinal web stiffener width
GPIN1	= Distance from work line to gudgeon pin
GQUOIN	= Distance along leaf work line from quoin contact point to gudgeon pin
GSLOPE	= Gate slope ratio (run:rise)
GTOP	= Distance from sill to top of skin
GUCPT	= Upstream flange cover-plate thickness
GUCPW	= Upstream flange cover-plate width
GUCPX	= Upstream flange cover-plate distance from quoin
GUF34W	= Upstream flange width from corner splice point to flange splice point
GUF4CW	= Upstream flange width from flange splice point to girder centerline
GUFCT	= Upstream flange thickness between end diaphragms
GUFET	= End zone upstream flange thickness
GUFEW	= End zone upstream flange width
GUFX4	= Distance from quoin to upstream flange splice point
GWCT	= Center zone girder web thickness
GWEBD	= Girder web depth
GWET	= End zone girder web thickness
GWORKL	= Distance from workline to downstream edge of girder web.
H	= Gate height (also used to differentiate a horizontal (H) skin leak from a vertical (V) skin leak
I	= Intercostal

L	= Left quoin bearing block leak (or boil)
L_1	= Downstream movement at top of gate
L_2	= Downstream movement at DSWL
LF	= Leak factor
LG	= Left gate facing downstream
LQ	= Land quoin
L_S	= Downstream movement at sill
m	= Equivalent structure age
M	= Miter bearing block leak (or boil)
MG_1	= Miter block gap at top of gate
MG_2	= Miter block gap at DSWL
MG_S	= Miter block gap at sill
n	= Number of longitudinal web stiffeners [Eq. 3.3]
NDS	= Number of diaphragm spaces between end diaphragms
NGIRD	= Girder number
NGIRDI	= Top girder of similar girder group
NGIRDN	= Bottom girder of similar girder group
NGIRDS	= Number of girders
NGLS	= Number of longitudinal stiffeners between girder flanges
NGWTS	= Number of transverse web stiffener spaces between adjacent intermediate diaphragms
NIS	= Number of intercostal spaces between adjacent diaphragms
NPANLI	= Top girder of similar skin plate panel
NPANLN	= Bottom girder of simlar skin plate panel
O_1	= Offset measurement at top of gate
O_2	= Offset measurement at DSWL
ODI	= Overall intercostal depth
O_s	= Offset at sill
Q_{G1}	= Quoin block gap at top of gate
Q_{G2}	= Quoin block gap at DSWL
Q_{GS}	= Quoin block gap at sill
R	= Right quoin bearing block leak (or boil)
RG	= Right gate facing downstream
RQ	= River quoin
S	= Skin plate
SPT	= Skin plate thickness
STEMT	= Thickness of perpendicular intercostal leg
t'	= Time since last repair or rehabilitation
t_s	= Longitudinal stiffener thickness [Eq. 3.3]
t_w	= Girder web thickness [Eq. 3.3]
V	= Vertical skin leak
VD	= Girder vertical distance above sill
w_i	= Weight factor
W_i	= Normalized weight factor
X	= Measurement of a distress
X_A	= Angular offset
X_B	= Total number of boils
XBUOY	= Distance along work line from quoin to the application point of ABUOY
X_C	= Contact offset
XDEAD	= Distance along work line from quoin to the application point of ADEAD

X_G = Girder measurement (cracks, dents, or corrosion)
X_I = Intercostal measurement (cracks, dents, or corrosion)
X_M = Elevation change at miter
$X_{[illegible]}$ = Maximum miter block gap
X_{max} = Limiting value of X
X_{max1} = Limiting movement of anchorage system, dimension 1
X_{max2} = Limiting movement of anchorage system, dimension 2
X_{max3} = Limiting movement of anchorage system, dimension 3
X_{maxA} = Limiting value of angular offset
X_{maxB} = Limiting value of boils
X_{maxC} = Limiting value of contact offset
X_{maxG} = Limiting girder measurement (cracks, dents, or corrosion)
X_{maxI} = Limiting intercostal measurement (cracks, dents, or corrosion)
X_{maxM} = Limiting miter movement (elevation change or gaps)
X_{maxQ} = Limiting quoin movement (elevation change or gaps)
X_{maxQM} = Limiting value of quoin and miter leaks
X_{maxS} = Limiting skin measurement (cracks, dents, or corrosion)
X_Q = Elevation change at quoin
X_{QM} = Sum of quoin and miter leaks
X_S = Skin measurement (cracks, dents, or corrosion)
Y_1 = Distance from walkway to measurement
Y_2 = Distance from walkway to measurement
ZBUOY = Distance from downstream edge of girder web to the application point of ABUOY
ZDEAD = Distance from downstream edge of girder web to the application point of ADEAD