PREDICTING AND PROLONGING THE LIFE OF USED CRANES

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BACKGROUND

So you have an older crane that has not undergone regular structural inspection—what are your options? You can do nothing and blindly use the crane, which, as we will explain later, is risky. Or you can assess its condition to find out how much structural life remains. Once you know the condition, you can decide how to best use the crane.

How does one assess the condition of a crane? One method is to predict how many more containers can be handled before the crane structure becomes unreliable. If you decide to keep the crane, prolonging the life of the crane becomes an issue.

Liftech's techniques of predicting and prolonging the structural life of used cranes are discussed in this paper. Liftech provided this service for quayside container cranes and rail mounted gantry cranes in Hongkong International Terminals, Hong Kong. These cranes will be presented as case studies.

To fully assess the condition of a crane, one must also look at the mechanical and electrical aspects of the crane. This paper only addresses structural issues.

DETERIORATION OF A USED CRANE

Corrosion and structural fatigue are two elements that cause a crane structure to deteriorate.

Corrosion is environmental and, if unchecked, can cause structural failure. However, corrosion is easy to evaluate.

Structural fatigue is crack growth in the steel structure that occurs under fluctuating loading. Fatigue has caused structural failure in bridges and cranes. Like corrosion, it has endangered life and property in numerous structures. This paper focuses on fatigue cracking rather than corrosion.

PREDICTING THE LIFE OF A USED CRANE

Definition of Useful Life

In this paper, the useful life of a used crane is defined as the duration that a crane can operate before the risk of failure due to fatigue cracking exceeds the normal industry standards. Before useful life analysis can be discussed, background information about fatigue and fatigue design will be provided.

Introduction to Fatigue

Millions of small undetectable cracks exist in all large steel structures. Some of these cracks will grow when fluctuating stresses are applied. If left unchecked, these cracks grow until failure occurs.

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Stress fluctuation is the only mechanism that causes the cracks to grow. The cracks grow by unzipping atomic bonds, which is analogous to splitting logs. See Figure 1.

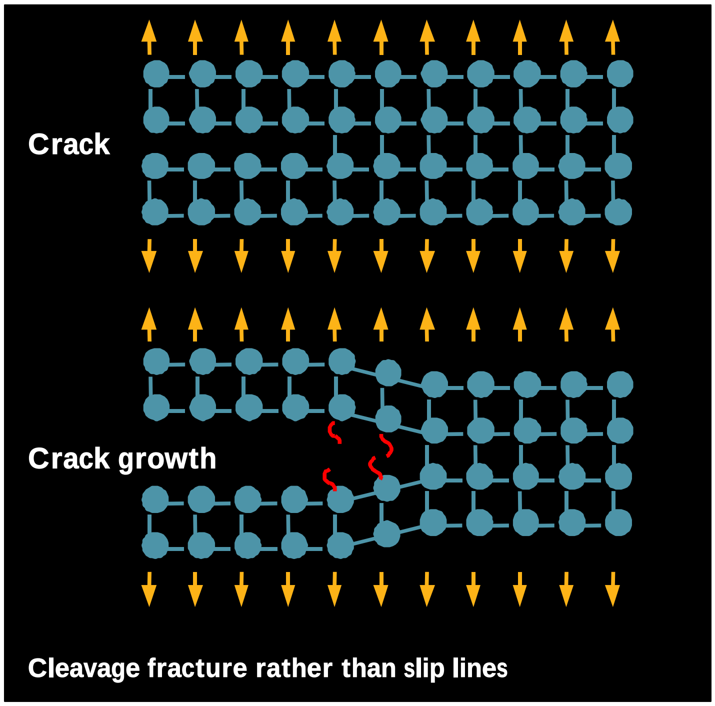

Figure 1

A few variables influence the rate of crack growth. The larger the fluctuating stresses, the faster the rate of growth. The rate of crack growth increases dramatically as the crack grows larger. Cracks also grow faster in thicker plates than thinner plates. But below a threshold stress range, cracks do not grow at all.

Most cracks occur at details that are poorly designed, poorly fabricated, or both. Welded connections are far more likely to crack than bolted connections, primarily because welding introduces flaws in both the weld metal and the base metal.

FATIGUE DESIGN

Modern fatigue design rules and codes, such as British Standards, prescribe allowable fluctuating stress ranges, given the number of cycles, for many different types of connections. These allowable fluctuating stress ranges are based on laboratory tests of various welded and bolted connection types.

There are two design philosophies: **safe life design** and **damage tolerant design**.

In **safe life design**, a structure is designed such that there is an acceptable reliability for the life of the structure. This design philosophy results in a heavy and conservative structure that is only economic for instances where regular inspection is not possible or practical.

In **damage tolerant design**, a structure is designed such that regular inspection is necessary to achieve an acceptable level of safety. For example, if regular inspection is necessary every three years, damage tolerant design is analogous to a safe life design of three years. Damage tolerant design is the only economic design philosophy for container handling cranes; thus, damage tolerant design is adopted by all current crane specifications.

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Another way to think about damage tolerant design is: if fatigue cracks were to occur in any given member, the remaining structure should be able to safely carry the load until a routine periodic inspection detects the crack. Therefore, the periodic inspection interval should be long enough to make the inspection economically feasible, but short enough to detect the crack before it reaches an unstable state.

Structures employing damage tolerant design require structural inspection programs and accessibility for regular inspection. Therefore, container cranes require structural inspection programs and accessibility for regular inspection. Manholes, ladders, and platforms are required to access all critical connections. The structural inspection program should define which connections to inspect, what technique to use, how often to inspect, how to report the findings, and procedures for repair once the cracks are discovered.

Although all cranes are designed with damage tolerant design, people in the industry often confuse the approach with safe life design. Often, proper access to critical connections is not provided, and/or regular structural inspection is disregarded. The lack of regular structural inspection is risky because the crane structure can become significantly less reliable than envisioned by the designer.

USEFUL LIFE ANALYSIS

Predicting fatigue crack growth is based on statistical data and the principles of fracture mechanics. Crack prediction based on the statistical approach is not perfect—the results from fatigue testing are extremely scattered.

The following are the steps of a useful life analysis:

1. Structural condition survey
2. Useful life estimate before inspection based on prediction of the number of cracks
3. Inspection program and structural inspection
4. Useful life estimate after inspection, assuming that detected cracks are repaired

Each step of the process is described in detail below.

1. Structural Condition Survey

The engineer's visual assessment provides valuable information about the crane's operations and the present crane condition. The condition survey provides a comparison between the "as-built" condition of the crane and the one shown on the manufacturer's drawings. The survey provides a means for the engineer to assess the condition of fracture critical members (FCMs) and determine whether they have any welded attachments that could accelerate fatigue crack growth.

Fracture critical members are tension members or tension components of members whose failure could lead to collapse of the crane, collapse of the trolley, or dropping the load. Welded attachments to FCMs can severely accelerate fatigue growth in an otherwise acceptable design, so elimination of wraparound weld details on the fracture critical members and connections is extremely important. Wraparound welds are prohibited by *ANSI/AWS D1.1, Structural Welding Code* and *ANSI/AASHTO/AWS D1.5, Bridge Welding Code*.

The fatigue life can be shortened by 2.5 times if a fillet weld is too near an edge of a member. A crack may initiate at a poor weld detail and grow into the parent metal of an FCM. Since fatigue cracks grow perpendicular to the principal stress, the crack will grow across the member. A seemingly harmless weld connecting a walkway, an electrical box, or a conduit fitting can lead to a serious failure.

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During the condition survey, the engineer takes extensive photographs of each joint. The photographs will be included in the structural inspection manual that will be used by the non-destructive testing (NDT) inspector to understand what to inspect and to report his findings.

2. Useful Life Estimate Before Inspection

The initial estimate of the remaining useful life of the crane, prior to an NDT inspection, is based on the current condition of the crane and on predicting the number of fatigue cracks in the crane.

For each crane, the engineer generates a computer model based on structural drawings and field information gathered during the condition survey. The fatigue and load spectrums are generated based on vessel operations, trolley loading, and the number of operating cycles. The fatigue spectrum describes the vessel loading and unloading operation for the trolley. The load spectrum describes the trolley loading and the number of cycles of operation during the life of the crane.

Normally, fatigue codes are used for the design of new structures, but they can also be used to predict the number of fatigue cracks in a used crane. The data provided by *British Standards 7608, Code of Practice for Fatigue Design and Assessment of Steel Structures*, is ideal for this application. As mentioned previously, fatigue codes are based on laboratory tests of various connection types. The codes use statistics to determine the allowable fluctuating stress ranges for the different connection types. This important feature of the fatigue codes allows the engineer to back calculate the number of fatigue cracks predicted.

Based on the predicted number of cracks and the anticipated future crane usage, an estimate of remaining useful life in years is calculated.

This initial assessment estimates the useful life of the crane prior to repairing the cracks. The estimated remaining useful life will increase after the crane is inspected and the cracks are repaired.

The initial estimate of the useful life provides information to the owner, which is useful for decision making. If the estimated life is short, and repairs are expensive and uneconomic, the owner may decide to scrap the cranes and forego an NDT inspection, which is described in the next section. If the estimated useful life is longer, the owner may decide to proceed with the NDT inspection.

3. Inspection Program and Structural Inspection

Before NDT inspection can proceed, the engineer must provide the inspector with an inspection program. The inspection program describes which connections to inspect, where to inspect, and how to inspect. The types of inspection may include visual, magnetic particle, ultrasonic, or radiographic.

4. Useful Life Estimate After Inspection

The actual number of fatigue cracks is determined from the NDT inspection.

The useful life is estimated based on expected use and the number of detected cracks.

After the cracks in the crane structure are repaired, the life typically improves by at least one inspection cycle, between three and six years.

PROLONGING THE LIFE OF A USED CRANE

Once the useful life of the crane is determined, other data is required for an economic assessment. Useful data includes the cost estimate to repair the cracks and to refurbish and maintain the crane. Refurbishment could include new drives, an outreach extension, and/or a crane raise. With this data, the crane owner can make a rational economic assessment of the used crane.

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If the owner determines that it is economic to continue to use the crane, the following is necessary to maintain the safety of the used crane:

First, all cracks detected by the structural inspection need to be repaired. Since most cracks occur at details that are poorly designed, poorly fabricated, or both, it is often important to not only repair the crack, but to improve the details. Engineering judgment must be used to prepare the repair procedure and/or redesign.

Second, a periodic inspection program needs to be implemented. Liftech's structural maintenance program includes preparation of an NDT inspection manual for each crane. A sample of Liftech's program is included at the end of this paper. The program addresses the following:

1. Structural details to be inspected
2. Whether each member detail is classified as FCM or NFCM (Non-FCM)
3. Method of locating each detail
4. Method of inspection: visual (VT), magnetic particle (MT), ultrasonic (UT), or radiographic (RT)
5. Inspector's qualifications
6. Required reporting procedure for the defect findings
7. Repair procedure
8. The frequency of inspection for different connections. Connections that are fracture critical or have higher stress ranges must be inspected more frequently

Rejuvenation

If a crack is detected in time and repaired before it becomes unstable, the metal in the vicinity of the repaired crack is rejuvenated, and the repaired joint is at least as good as new.

As cranes age, cracking patterns become more unpredictable, and the cracking frequency increases nonlinearly. However, if properly maintained, the frequency of occurrence of new cracks can be reduced. This phenomenon is due to three factors:

1. Cracks often appear at poor details, which should be made more fatigue resistant by the improvement.
2. The improved joints are given more attention than were given during manufacturing.
3. For every detail, there is a threshold stress range below which cracks do not propagate. Many connections have stress ranges below the threshold. If this applies to the area in question, once the defect is fixed, the remaining cracks in that area will not propagate.

See Figure 2 for a graphical illustration of this phenomenon.

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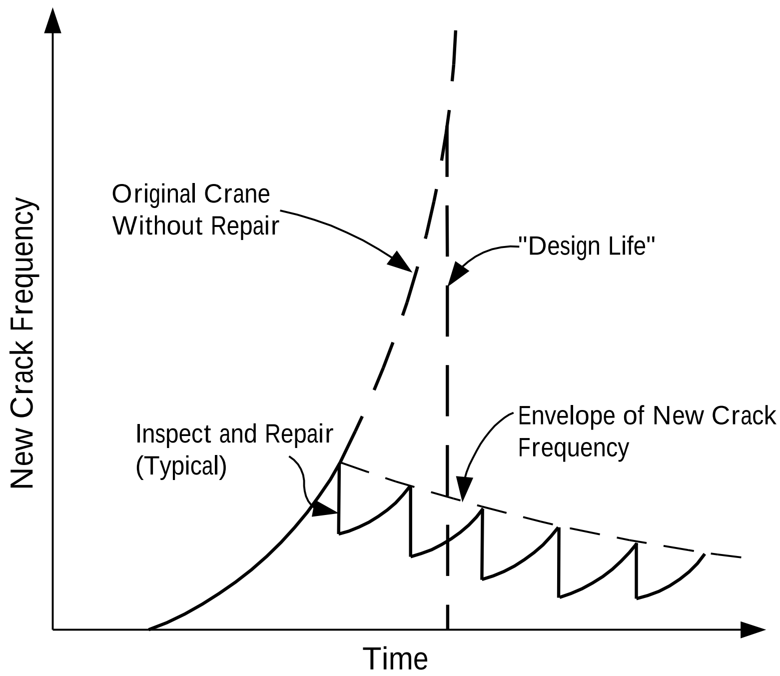

Figure 2

CONCLUSION

Liftech's techniques of predicting and prolonging the life of used cranes have been applied to many cranes worldwide. As you will see in the following two case studies, the results of the prediction using the statistical approach compares well with actual findings. The client was able to rationally decide what to do with the cranes, some of which were upgraded while others were moved to less demanding locations. The useful lives of the cranes were significantly extended with the repairs and the newly implemented structural inspection programs will help maintain a high reliability of safety for the structures.

CASE STUDY #1 – HIT QUAYSIDE CONTAINER CRANES

In 1999, Liftech Consultants Inc. was retained by Hongkong International Terminals to assess the structural useful life of eight dockside cranes manufactured by Paceco/MES, IHI, and Hitachi. The cranes had been operating for 14 to 28 years. HIT wished to operate the cranes for an additional 10 years if the structures had low risks of catastrophic failure.

Quay Crane Data

All cranes had the trolley travel drive machinery on the trolley frames. The Paceco/MES cranes had truss-type booms. The IHI cranes had twin plate girder booms, with the trolley rails on the outside of the plate girders. The Hitachi cranes had twin rectangular box girder booms with the trolley rails on the inside of the girders. See Table 1.

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Table 1

Crane I.D.	Yr com-missioned	SWL under spreader	Outreach/Back-reach/Gage	No. of lifts based on twistlock count
Paceco 63 Paceco 71	1972	32.7 LT (revised from 35 LT)	36m/ 9.14m/ 24.38m	2,600,000 2,650,000
IHI 41 IHI 43 IHI 61 IHI 64	1976	40 LT	36.6m/ 9.14m/ 24.38m	2,100,000 2,200,000 2,300,000 2,400,000
Hitachi 42 Hitachi 62	1985	35 LT	36.6m/ 9.14m/ 24.38m	1,500,000 1,450,000

Condition Survey

In general, the cranes were found to be in good condition. Hitachi 62 was in the best condition. Corrosion and other non-fatigue related problems were found, but will not be discussed in this paper.

Indications of cracks were on all cranes and were noted in the NDT inspection manuals.

Cumulative Damage Analysis and Inspection Interval Estimates

Liftech performed cumulative damage analyses for the three different types of cranes, based on the crane operating data provided by HIT and the assumed fatigue design criteria.

In addition to an annual visual inspection of the cranes, Table 2 shows the recommended inspection intervals for a few sample members of the Paceco/MES cranes. Similar tables were also generated for the other cranes. The table identifies NFCM and FCM classifications. The inspection interval is either the number of container moves or the number of years from the latest inspection, whichever occurs first.

Table 2

NDT INSPECTION INTERVALS FOR PACECO/MES CRANES

Component	FCM/NFCM	Inspection interval lesser of	
		No. of moves	Years
Frame			
Landside Trolley Girder Connection	FCM	300,000	3
Landside Trolley Girder Support Beams	FCM	600,000	6
Waterside Trolley Girder Support Beams	FCM	1,200,000	12
Portal Beam	NFCM	2,400,000	24
Boom			
Diagonal @ Upper chord	NFCM	300,000	3
Forestay	FCM	600,000	6
Braces @ Upper Chord	NFCM	1,200,000	24

See Figure 3 for a diagram showing the names of the crane components.

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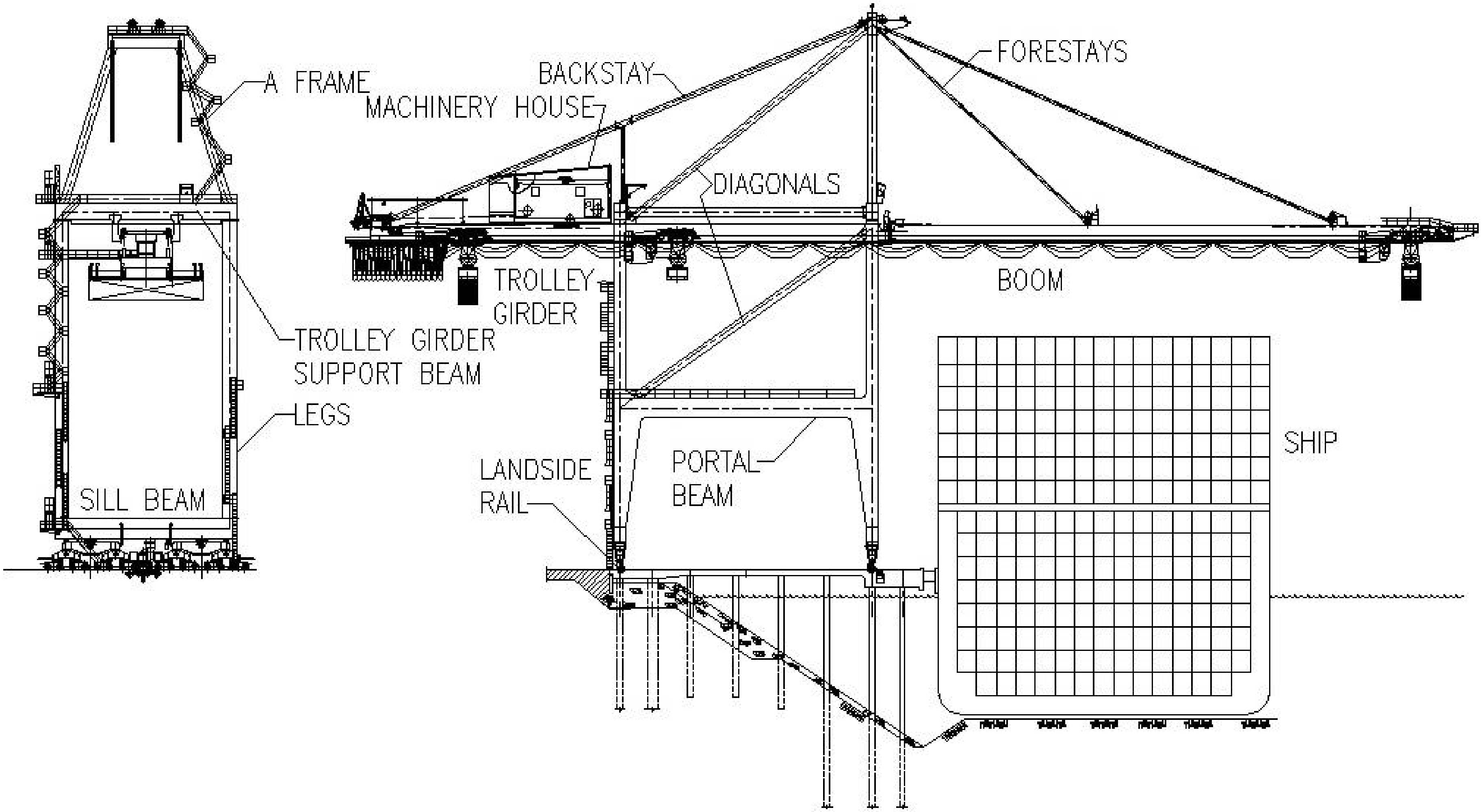

Figure 3: Crane Anatomy

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Only a few of the crane structural members required inspection once every three years. The remaining members needed to be inspected at 6, 12, or 24-year inspection intervals, which is economic. A three-year inspection interval for all joints is excessive, and a six-year interval is probably excessive for some joints and inadequate for others. Using the inspection intervals shown above, the required down time to inspect the cranes would be significantly reduced.

Estimated Fatigue Crack Frequency vs. Actual Fatigue Cracks Documented in NDT Inspection

Based on the crane operating data provided by HIT and the assumed fatigue design criteria for the MES, IHI, and Hitachi cranes, the expected numbers of detectable fatigue cracks were calculated at current maintenance levels, prior to an NDT inspection.

An NDT inspection was then performed on each crane. The inspection provided data about the actual cracking pattern for the cranes. The table below compares the predicted number of fatigue cracks for each set of cranes at current maintenance levels vs. the actual fatigue cracks detected during the NDT inspection. Fatigue cracks are those cracks that originated at FCM weldments as a result of cyclical container loading of the crane structure.

Table 3

Crane I.D.	Predicted no. of fatigue cracks	Fatigue cracks detected during NDT inspection
Paceco 63	33 to 36	13
Paceco 71	35 to 38	7
IHI 41	3 to 5	2 to 3
IHI 43	3 to 5	5
IHI 61	4 to 6	12
IHI 64	6 to 8	11
Hitachi 42	0 to 1	2
Hitachi 62	0 to 1	3

The actual fatigue cracking pattern for IHI 41 and 43, and Hitachi 42 and 62 mimicked the predicted pattern quite closely. There was a significant variation in the other cranes.

Since the relative cumulative damage varies as the cube of the stress range, a small variation in the stress range magnifies the relative cumulative damage significantly. For the Paceco/MES and the Hitachi cranes, the average moving loads used in the analysis were 74 kips and 70 kips, respectively. A 10% reduction in this weight would account for most of the variation in the cracking pattern. The test data had a large scatter, which accounted for some of the statistical variations. The combination of both effects probably accounted for the sharp difference in the cracking patterns.

Useful Structural Life Assessment

Table 4 compares the estimated future structural life for each crane at a reliability of 97.73%, prior to NDT inspection, after NDT inspection, and after all repairs were completed.

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Table 4

	STRUCTURAL LIFE EXPECTANCY		
	Prior to NDT inspection	Based on NDT inspection results	After all repairs are completed
Crane I.D.	Years	Years	Years
Paceco 63	0 to 1	6 to 7	11 to 12
Paceco 71	0 to 1	10 to 11	15 to 16
IHI 41	12 to 13	16 to 18	20
IHI 43	12 to 13	10 to 12	15 to 17
IHI 61	10 to 11	5 to 7	10 to 12
IHI 64	8 to 9	6 to 7	11 to 12
Hitachi 42	15 to 16	10 to 11	15 to 16
Hitachi 62	16 to 17	8 to 10	13 to 14

After repairs are complete, the structural life expectancy of the cranes would be increased by approximately one inspection period, except for IHI 41, where the structural life expectancy was limited to the twenty-year design life. This was reasonable, since the repaired areas were now rejuvenated and the metal in the vicinity of the repairs had an improved reliability.

When all recommended repairs are completed, we estimate the useful remaining structural life of the cranes to be between 10 and 20 years, as shown in the table above. We expect the crane structures will outlive the mechanical and electrical systems.

Recommendations

Repairs were recommended to eliminate all wraparound weld details on the fracture critical members and their connections. The fracture critical members are the forestays, backstays, upper diagonal pipes, trolley girders, booms, both trolley girder support beams, and portions of the trolley structure.

Other areas that needed attention were welded attachments to the trolley girders and other FCMs on the Paceco/MES, IHI, and Hitachi cranes. Modifications were provided in our report to HIT.

Action of the Client

The recommended structural repairs were completed. With the structural maintenance program, the remaining structural lives of all eight cranes are at least ten years.

With the forecast of increasing throughput, HIT wants to improve the berthing facility where five panamax cranes operate to handle post-panamax vessels. Two IHI cranes, which have the largest number of weld defects, are being considered for transfer to other operationally less demanding terminals within the Hutchison Port Holdings (HPH) group. For the remaining six cranes, HIT is considering retrofitting the electrical controls and drive systems at a rate of two cranes per year.

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CASE STUDY #2 – HIT RAIL-MOUNTED GANTRY CRANES

In 2001, Hongkong International Terminals again retained Liftech to assess the structural useful life of their cranes—this time, one 1984 Mitsui Engineering and Shipbuilding Co. (MES) quayside crane, and twenty-four 1995 Mitsubishi Heavy Industries (MHI) rail-mounted gantry cranes (RMGCs). The MHI RMGCs are the focus of this case study. HIT wanted to obtain information regarding the expected structural life and to initiate structural maintenance programs for each crane.

RMGC Data

Each crane was designed for 1-over-6 container operations, with a 30.07-m gantry rail span, 4.2-m outreach and backreach, and a 41-ton rated load. Each trolley had a 15.8-m wheel gage and a 4.6-m wheel base. At the time of the assessment, the cranes had twistlock counts varying from 301,000 to 694,000, as shown in Table 5. See Figure 4 for the RMGC orientation.

Table 5

Mnfctr.	Crane I.D.	Number of lifts based on twistlock count
MHI	QR1 to QR4	445,000 to 663,000
MHI	RR1 to RR4	467,000 to 671,000
MHI	SR1 to SR4	301,000 to 694,000
MHI	TR1 to TR4	445,000 to 646,000
MHI	UR1 to UR4	443,000 to 620,000
MHI	VR1 to VR4	416,000 to 607,000

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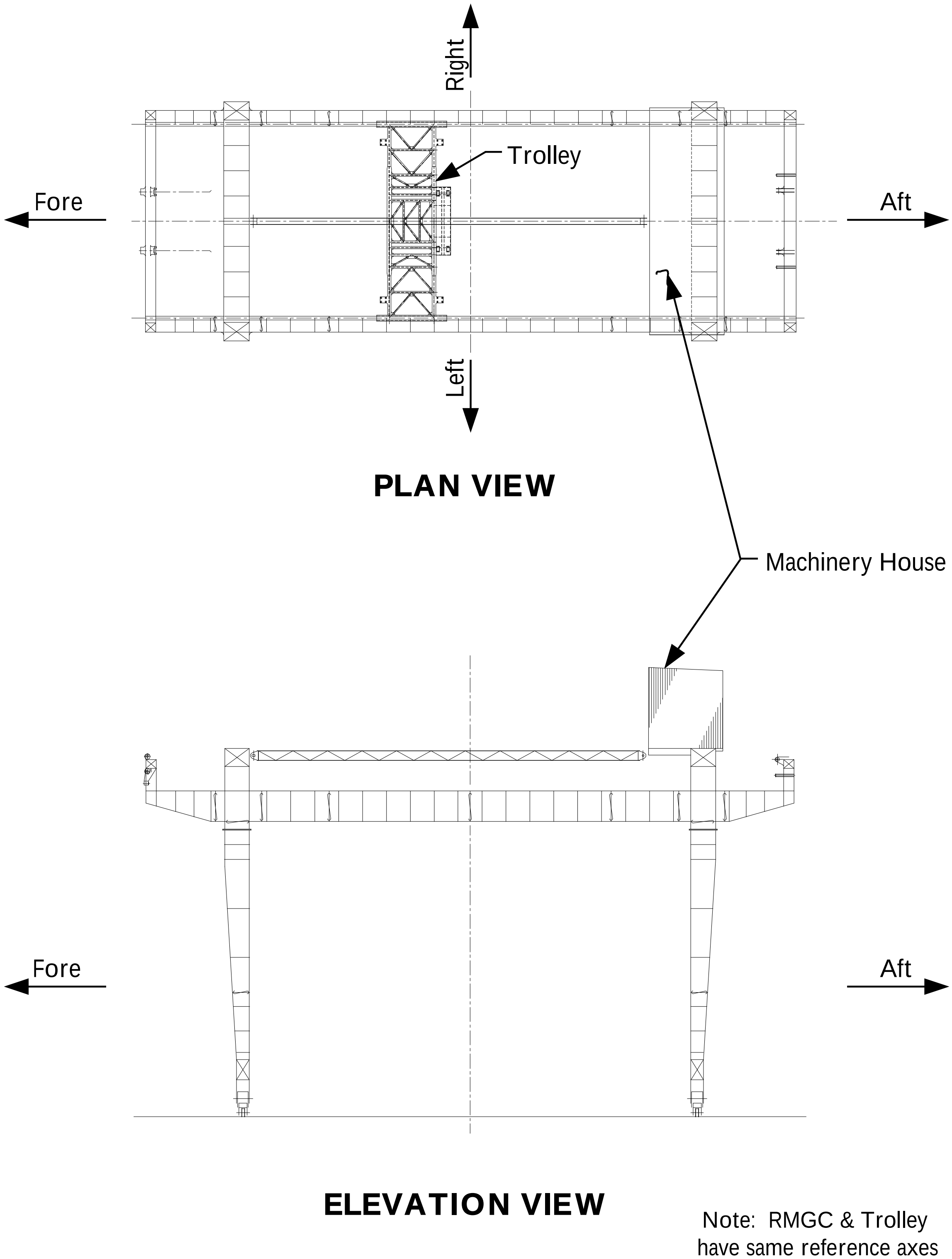

Figure 4: RMGC Orientation

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Condition Survey

At the time of the condition survey, the cranes were six years old and had not been inspected using NDT techniques such as MT, UT, or RT. In general, the cranes were found to be in good structural and operational condition. Slight corrosion and other non-fatigue-related problems were found, but will not be discussed in this paper.

Cumulative Damage Analysis and Inspection Interval Estimates

Liftech performed a cumulative damage analysis for each of the 24 cranes based on operating data provided by HIT and an assumed fatigue design criteria.

The study concluded that after the initial NDT inspection, the cranes should be visually inspected each year.

Table 6 shows the recommended inspection interval, in addition to the annual visual inspection, for each component and identifies NFCM and FCM components. The trolley girder, the forward and aft trolley girder end ties, and the trolley structure should be inspected using MT and UT methods every six years or 750,000 container moves. All other RMGC components should be MT and UT inspected every twelve years or 1.5 million container moves. The inspection interval is either the number of container moves or the number of years from the latest inspection, whichever occurs first.

Table 6

Component	FCM / NFCM	Inspection intervals lesser of	
		No. of moves	Years
RMGC Frame			
Upper legs, aft	FCM	1,500,000	12
Lower legs, aft	NFCM	1,500,000	12
Upper legs, fore	FCM	1,500,000	12
Lower legs, fore	NFCM	1,500,000	12
Sill beams	NFCM	1,500,000	12
Leg tie beam, aft	NFCM	1,500,000	12
Leg tie beam, fore	NFCM	1,500,000	12
Trolley girder @ cantilevers-upper flange	FCM	750,000	6
Trolley girder @ cantilevers-lower flange	NFCM	750,000	6
Trolley girder between legs-upper flange	NFCM	750,000	6
Trolley girder between legs-lower flange	FCM	750,000	6
Trolley girder end tie-aft side	NFCM	750,000	6
Trolley girder end tie-fore side	NFCM	750,000	6
Gantry	NFCM	1,500,000	12
Trolley			
Structure	FCM	750,000	6
Structure	NFCM	750,000	6

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Estimated Fatigue Crack Frequency vs. Actual Fatigue Cracks Documented in NDT Inspection

Based on crane operating data provided by HIT, and the assumed fatigue design criteria for the cranes, the expected number of detectable fatigue cracks prior to NDT inspection was estimated to be zero to one for each crane.

An NDT inspection was then performed on RMGCs QR2 and SR1. Ten cracks were detected on crane QR2. Of these ten cracks, one crack was detected at the surface of a transverse butt weld at the top flange of a trolley girder cantilever section. This crack was on an FCM, most likely related to fatigue damage. All other cracks occurred at NFCMs. No cracks were discovered on SR1. Crane QR2 represented an RMGC with a high twistlock count, whereas SR1 represented one with a low to average twistlock count. These results compare extremely well with estimates discussed above.

Useful Structural Life Assessment

Table 7 shows the estimated future structural life expectancy at current usage levels for each crane at a reliability of 97.73%.

Table 7

	STRUCTURAL LIFE EXPECTANCY	
	Prior to NDT inspection	**Based on NDT inspection results** (subject to change)
Crane I.D.	**Years**	**Years**
QR2, QR3, RR2, RR3	16 to 18	16 to 18
RR4, SR2, SR3, TR3		
TR2, UR2, UR3, VR1, VR3	18 to 20	18 to 20
QR4, SR4, TR4, VR2, VR4	20 to 22	20 to 22
QR1, RR1, TR1, UR1, UR4	26 to 29	26 to 29
SR1	40	40

The recommended inspection intervals and life expectancies may change if the data collected from the initial NDT inspections of the remaining 22 RMGCs, which have not yet been performed, differ significantly from the theoretical crack predictions. We do not expect any significant changes, however.

We expect the crane structure to outlive the mechanical and electrical systems.

Recommendations

Several cranes had wraparound welds, such as that shown in Figure 5. In addition, several conduit, handrail, and walkway attachments to the trolley girder and other FCMs were discovered. Recommendations were made to improve all of these details.

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Figure 5

Due to the yard layout, the two middle RMGCs in each row had significantly higher twistlock counts than the two outer RMGCs. This, of course, leads to additional fatigue damage on the middle RMGCs. To distribute the fatigue damage more evenly between all of the RMGCs, we recommended that the middle cranes be switched with the outer cranes in each row when the twistlock counts of the inner cranes reach 1.2-million.

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RELATED MATERIAL

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Appendix

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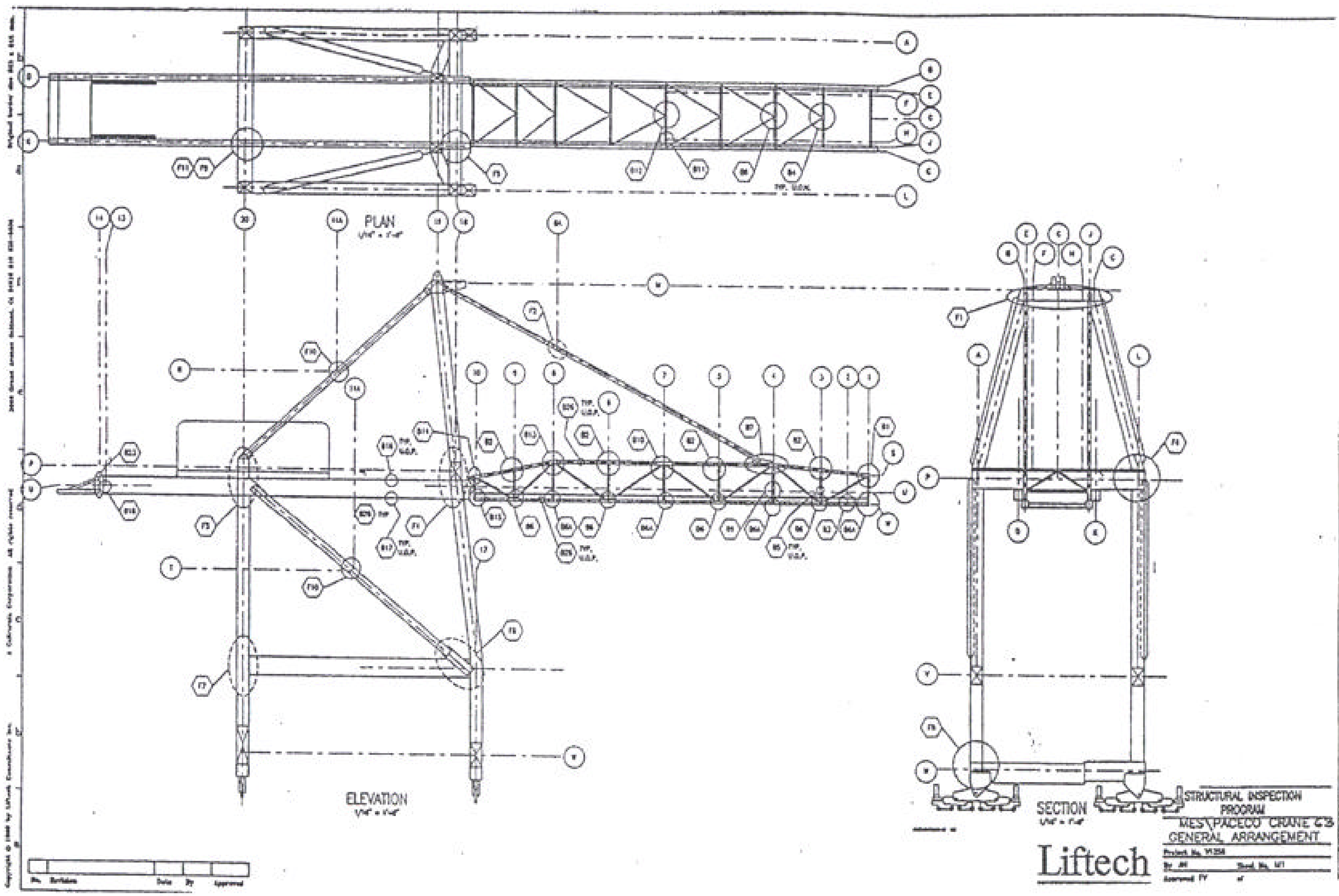

Sample General Arrangement in Inspection Program

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By JRD App'd FV

Welded Joints Nomenclature

Pipe	k
Bolt:	b
Gusset:	g
Plate:	p
Stiffener:	s
Wide Flange:	w
Channel:	c
Tee:	i
Angle:	a
Tube:	t
Far Side:	FS
Weld No.:	1, 2, 3, ...

Examples:

Plate to wide flange:	pwl
Gusset to plate:	gp3
Stiffener to plate:	sp5

Joint and Weld Identification

15 B R - B1 or F1 - gp2 (VT-2)

- Weld Class 2
- Visual Testing
- Weld Gusset to Plate 2
- Frame Detail
- Boom Detail
- Grid Letter } Intersection of
- Station Number }

TEST ABBREVIATIONS:

Type of Test	Symbol
Visual	VT
Magnetic Particle	MT
Ultrasonic	UT
X-Ray	XT

WELD CLASSES:

Weld class 1 is fracture critical members (FCM). Weld class 2 is non-fracture critical members (NFCM). Weld class 3 is secondary members.

LOCATION IDENTIFICATION:

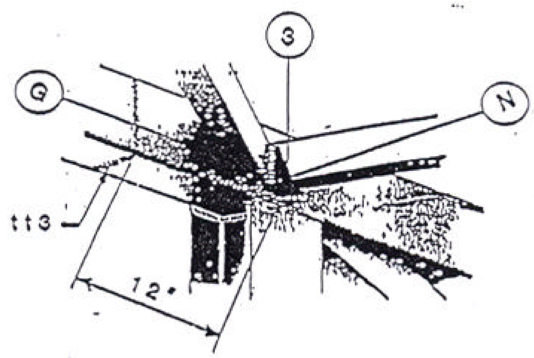
For weld defects found between stations, describe location of defect: distance in inches to the nearest station, waterside or landside from the station, up or down and/or outboard or inboard side of the joint.

Example:

3GN/tt3 - 12" - 3 - LS - OB

This reads: "Defect in joint 3GN, weld tt3, 12" from grid 3, landside, outboard."

bam0:jobdata b785 welded joints



EXAMPLE JOINT 3GN

V1258/ HIT- HITACHI QC 42 STRUCTURAL INSPECTION 01/14/00 G3 of 3

Typical Inspection Program Page

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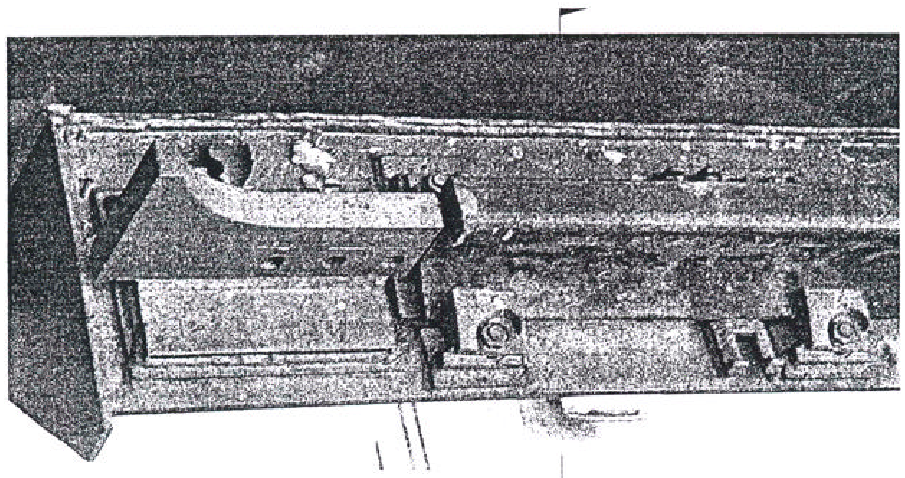
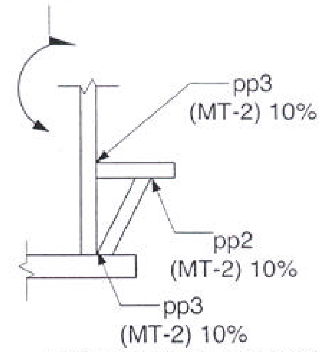
By AH/JRD Approved FV





B1

p:\v1258\dwg\visio\working images\hitachi\girder\b1.vsd

Weld I.D	Type of Test			Accept	Reject	Remarks	By	Date
	VT	MT	UT					

Equipment used:

If defect detected, indicate if:
RS,LTS,WS,LS,IB,OB,U,L.

Joint: 1D✓

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Typical Inspection Program Page

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