MARINE OIL TERMINAL ENGINEERING AND MAINTENANCE STANDARDS (MOTEMS) IMPLEMENTATION AND UPDATES

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Abstract

The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) became an enforceable part of the California Building Code on February 6, 2006. Engineering audits for high risk marine oil terminals must be completed by August 6, 2008. High risk facilities are determined by the total volume of flowing and stored oil; lower risk levels are determined based on the number of transfers per year and the maximum size of vessels that may call on the terminal. The MOTEMS are currently being used for new design and construction. A number of updates are currently being proposed, including a reduction in run-up heights for potential tsunamis in the San Francisco Bay, a new methodology to calculate forces on moored vessels, from passing vessels and a new equation to determine design loads for multiple quick release mooring hooks. Currently under development is a new, alternate method to determine the structural performance of wharf/pier structures. This new methodology should be completed in late 2007.

Introduction

In order to protect the public health, safety and the environment, the California legislature passed the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act of 1990 (the "Act"). The Act defines specific tasks for the California State Lands Commission ("the commission"), in part stating:

> *"The commission shall adopt rules, regulations, guidelines and commission leasing policies for reviewing the location, type, character, performance standards, size and operation of all existing and proposed marine terminals within the state, whether or not on lands leased from the commission, and all other marine facilities on land under lease from the commission to minimize the possibilities of a discharge of oil…" (California Public Resources Code (PRC) Section 8755 (a))*
>
> *"The commission shall periodically review and accordingly modify its rules, regulations, guidelines and commission leasing policies to ensure that all operators of marine terminals within the state and marine facilities under the commission's jurisdiction always provide the best achievable protection of the public health and safety, and the environment " (PRC Section 8756).*

In order to fulfill this mandate, the Marine Facilities Division (MFD) of the California State Lands Commission (CSLC) requested a FEMA hazard mitigation grant to develop a set of performance standards for marine oil terminals in California. With additional funding from CSLC, the “Marine Oil Terminal Engineering and Maintenance Standards” or MOTEMS were developed. Han-Padron Associates of Long Beach and Ben C. Gerwick, Inc of San Francisco wrote the initial draft, as part of a joint venture. Through a series of technical advisory committees, industry and academic input and MFD engineering staff review, a final version of the MOTEMS was submitted to the CSLC for approval and to the California Building Commission for adoption. The MOTEMS became an enforceable part of the California Building Code, Title 24, Part 2, Chapter 31F, “Marine Oil Terminals” on February 6, 2006 (Ref. 1). These standards define criteria for both new and existing facilities and are "performance-based" in terms of structural analysis and design.

The following summarizes the eleven sections of the MOTEMS:

- **Section 1** provides an overview, defines specific peer review requirements and gives a flowchart of the tasks required for the engineering audit, post-event (earthquake, vessel impact) inspections and engineering analyses.

- **Section 2** provides criteria for underwater inspections and tables to summarize the evaluation results for the structure (above and underwater) along with piping, fire, mechanical and electrical systems.

- **Section 3** provides the criteria for the structural loads to be applied to a marine oil terminal for the requisite analyses. These include dead, live, earthquake, mooring, berthing and other types of loads. The combination of the loads for design purposes is also provided.

- **Section 4** describes the acceptable methods of seismic analysis and provides the specific performance criteria for two levels of earthquake motion to be used in the seismic assessment. These performance goals are:

  Level 1 Earthquake: No or minor structural damage without interruption in service or with minor temporary interruption in service.

  Level 2 Earthquake: Controlled inelastic behavior (prevention of structural collapse) with repairable damage resulting in temporary closure of service, restorable within months and the prevention of a major spill.

- **Section 5** provides mooring and berthing analysis and design criteria, in order to establish the loads on the structure, and the requisite procedures to analyze mooring/berthing vessel loads.

- **Section 6** provides a screening process for geotechnical hazards, such as liquefaction or general soil failure. These procedures are based on state-of-the-art methods developed by the Southern California Earthquake Center (SCEC).

- **Section 7** provides the performance standards, in terms of allowable component displacement, as the structure is subjected to the applied loads. Methodologies for the analyses of reinforced and prestressed concrete, steel and timber components are included.

- **Section 8** provides the minimum requirements for fire prevention, detection and suppression. Many of the requirements are taken from various industry guidelines. This section mandates fire water volumes and flow rates, based on vessel size and product flammability.

- **Section 9** provides engineering criteria for pipelines. It also describes the process required to perform a pipeline stress analysis, which may be required to account for seismic displacement (from the structural analysis prescribed in sections 3, 4 and 7).

- **Section 10** provides general criteria for the mechanical systems of marine oil terminals, including loading arms, lifting equipment and gangways to the vessel.

- **Section 11** provides criteria for the electrical systems of a marine oil terminal, including requirements for hazardous areas, identification of critical equipment, grounding and bonding, illumination and corrosion protection.

In addition to the engineering analyses required for the audit, there are two general types of deficiencies that are to be reported:

Condition Assessment Ratings (CARs)

Above and below the water line structural assessments are designated as CAR's (See MOTEMS Table 31F-2-5, below), with one value for above and another value for below the water line. Ratings below "fair" (4) indicate that the structure is not fit-for-purpose, and some sort of reduction in the operational status may be required. Remedial actions must be taken, in order to restore full operational status.

TABLE 31F-2-5

CONDITION ASSESSMENT RATINGS (CAR)

Rating		Description of Structural Systems Above and Below Water Line
6	**Good**	No problems or only minor problems noted. Structural elements may show very minor deterioration, but no overstressing observed. The capacity of the structure meets the requirements of this standard. The structure should be considered fit-for-purpose. No repairs or upgrades are required.
5	**Satisfactory**	Limited minor to moderate defects or deterioration observed, but no overstressing observed. The capacity of the structure meets the requirements of this standard. The structure should be considered fit-for-purpose. No repairs or upgrades are required.
4	**Fair**	All primary structural elements are sound; but minor to moderate defects or deterioration observed. Localized areas of moderate to advanced deterioration may be present, but do not significantly reduce the load bearing capacity of the structure. The capacity of the structure is no more than 15 percent below the structural requirements of this standard, as determined from an engineering evaluation. The structure should be considered as marginal. Repair and/or upgrade measures may be required to remain operational. Facility may remain operational provided a plan and schedule for remedial action is presented to and accepted by the Division.
3	**Poor**	Advanced deterioration or overstressing observed on widespread portions of the structure, but does not significantly reduce the load bearing capacity of the structure. The capacity of the structure is no more than 25 percent below the structural requirements of this standard, as determined from an engineering evaluation. The structure is not fit-for-purpose. Repair and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted or contingency basis until the deficiencies are corrected provided a plan and schedule for such work is presented to and accepted by the Division.
2	**Serious**	Advanced deterioration, overstressing or breakage may have significantly affected the load bearing capacity of primary structural components. Local failures are possible and loading restrictions may be necessary. The capacity of the structure is more than 25 percent below than the structural requirements of this standard, as determined from an engineering evaluation. The structure is not fit-for-purpose. Repairs and/or upgrade measures may be required to remain operational. The facility may be allowed to remain operational on a restricted basis until the deficiencies are corrected, provided a plan and schedule for such work is presented to and accepted by the Division.
1	**Critical**	Very advanced deterioration, overstressing or breakage has resulted in localized failure(s) of primary structural components. More widespread failures are possible or likely to occur and load restrictions should be implemented as necessary. The capacity of the structure is critically deficient relative to the structural requirements of this standard. The structure is not fit-for-purpose. The facility shall cease operations until deficiencies are corrected and accepted by the Division.

Remedial Action Priorities (RAPs)

These deficiencies are called "Remedial Action Priorities" or RAPs and are most commonly used for piping, mechanical, fire or electrical problems (See MOTEMS Table 31F-2-6, below). Some of these must be corrected immediately (P1) as they pose a threat to the public health, safety and the environment. Others, (such as a “P4”) may indicate mild corrosion on pipelines, or the lack of paint, etc. These low priority deficiencies can be corrected during normal maintenance cycles.

TABLE 31F-2-6

COMPOENT DEFICIENCY REMEDIAL ACTION PROPRITIES (RAP)

Remedial Priorities	Description and Remedial Actions
P1	Specified whenever a condition that poses an immediate threat to public health, safety or the environment is observed. Emergency Actions may consist of barricading or closing all or portions of the berthing system, evacuating product lines and ceasing transfer operations. The berthing system is not fit-for-purpose. Immediate remedial actions are required prior to the continuance of normal operations.
P2	Specified whenever defects or deficiencies pose a potential threat to public health, safety and the environment. Actions may consist of limiting or restricting operations until remedial measures have been completed. The berthing system is not fit-for-purpose. This priority requires investigation, evaluation and urgent action.
P3	Specified whenever systems require upgrading in order to comply with the requirement of these standards or current applicable codes. These deficiencies do not require emergency or urgent actions. The MOT may have limitations placed on its operational status.
P4	Specified whenever damage or defects requiring repair are observed. The berthing system is fit-for-purpose. Repair can be performed during normal maintenance cycles, but not to exceed one year.

As audits are completed, action plans are to be submitted, providing a schedule as to when rehabilitation, if required, is to be performed. The MOTEMS does not place firm dates to complete rehabilitation, but relies on a schedule, mutually agreed upon by the operator and the MFD. Various levels of “follow-up actions” are described in MOTEMS Table 31F-2-7 (See below). Consideration is given for obtaining requisite permits, metocean limitations on construction schedules, etc. However, if the deficiency is critical, it may cause the operational status of the facility to be downgraded until the rehabilitation is complete. The MFD will track the deficiencies and monitor the construction, to be sure that the schedule is maintained and that the operator is performing the repairs as approved.

TABLE 31F-2-7 STRUCTURAL FOLLOW-UP ACTIONS	
Follow-up Action	**Description**
Emergency Action	Specified whenever a condition which poses an immediate threat to public health, safety or the environment is observed. Emergency Actions may consist of barricading or closing all or portions of the berthing system, limiting vessel size, placing load restrictions, evacuating product lines, ceasing transfer operations, etc.
Engineering Evaluation	Specified whenever structural damage or deficiencies are observed which require further investigation or evaluation, to determine appropriate follow-up actions.
Repair Design Inspection	Specified whenever damage or defects requiring repair are observed. The repair design inspection is performed to the level of detail necessary to prepare appropriate repair plans, specifications and estimates.
Upgrade Design and Implementation	Specified whenever the structural system requires upgrading in order to comply with the requirements of these standards and current applicable codes.
Special Inspection	Typically specified to determine the cause or significance of non-typical deterioration, usually prior to designing repairs. Special testing, laboratory analysis, monitoring or investigation using non-standard equipment or techniques are typically required.
Develop and Implement Repair Plans	Specified when the Repair Design Inspection and required Special Inspections have been completed. Indicates that the structure is ready to have repair plans prepared and implemented.
No Action	Specified when no further action is necessary until the next scheduled audit or inspection.

In order to facilitate the understanding of the MOTEMS, the MFD hosted workshops in early 2006, in both Northern and Southern California. In addition, an "Audit Manual" has been made available, that provides MOTEMS questions and correlates them with the numbering scheme of the standards. The intent is to provide field and office direction to facilitate the use of these new standards.

(MOTEMS) Implementation

The audit deadlines and also the seismic assessment are determined by the terminal's rating as "high", "medium" or "low". The definitions are as described in MOTEMS Table 31F-4-1 (See below):

TABLE 31F-4-1 *MOT RISK CLASSIFICATION*			
Risk Classification	***Exposed Oil (bbls)***	***Transfers per Year per Berthing System***	***Maximum Vessel Size (DWTx1000)***
High	*≥1200*	*N.A.*	*N.A.*
Moderate	*<1200*	*≥90*	*≥30*
Low	*<1200*	*<90*	*<30*

The calculation of "Exposed Oil" is the total volume of flowing oil and stored in the pipelines. The flowing oil is based on the 30 or 60 second shutdown time of the Emergency Shut Down (ESD) valve(s). If the terminal was operational prior to November 1, 1980 the shutdown time is 60 seconds, and if after this date, the time is 30 seconds. Based on the sum of these two volumes, the "exposed oil" is calculated. Table 31F-4-1 also makes use of the number of transfers per year and the maximum vessel size. If any of these three criteria variables (exposed oil, number of transfers, maximum vessel size) are met, then the facility falls into that category. For example, even if the total oil at risk is less than 1200 barrels, but there are more than 90 transfers per year, the facility is still rated "high". A typical low risk facility is a barge terminal, with low flow rates and short pipeline runs (i.e. a very limited amount of oil stored in the pipelines).

Without calculating the oil volumes, we estimate the number of terminals in California in each risk category is:

High risk	13
Medium Risk	11
Low Risk	8

After a facility determines their "risk classification", the next step is to determine when the initial audits are due. MOTEMS Table 31F-2-1 (See below) provides the initial deadlines for the audits. Operators should be aware that these are the dates wherein the audits are to be submitted to MFD for review and approval.

TABLE 31F- 2-1

INITIAL AUDIT REPORT SUBMISSION DEADLINE FOR EXISTING BERTHING SYSTEMS

Risk Classification[1]	***Submission Deadline[2]***
High	*30 Months*
Medium	*48 Months*
Low	*60 Months*

1 As defined in Tables 31F-4-1
2 From the effective date of this Chapter (31F)

Depending on the results of the initial audit, subsequent audits (of the underwater portions of the terminal) may be required every one to six years. An above the water audit is required once every three years.

In addition to the engineering audits, any significant change, modification or re-design of a structural, mooring, fire, piping/pipelines, mechanical or electrical system at an existing terminal is subject to review/approval prior to use or re-use.

If the facility has not had a mooring/berthing assessment performed, it will be required as a part of the audit. "Grandfathering" of facilities, where an operator was granted permission to use the historical largest vessel calling at the facility in his operations manual will no longer be permissible. Maximum vessel size must be based on a mooring assessment, with limitations on wind and current.

The MOTEMS is being used for two new structures, one in the Port of Los Angeles and the other in the Port of Long Beach. A new marine oil terminal is currently in the design phase, within the Port of Los Angeles, and a new alternate power breasting dolphin is being designed for the Port of Long Beach. Both of these projects are using the MOTEMS.

In addition to the California Building Code, the seismic portion of the MOTEMS has been incorporated into an international reference (Ref. 2). In addition, the MOTEMS is now referenced in the 2003 edition of the "National Earthquake Hazard Reduction Program" (Ref. 3). And most recently, the MOTEMS has become the approved methodology for the seismic assessment of all US military wharf/pier facilities (Ref. 4).

MOTEMS Updates

Since the original MOTEMS has been published and is now a California standard, the MFD has continued to refine and update the code. Some of the areas that will be improved/updated in the next code revision include:

a. San Francisco Bay Tsunami Study

A recently completed study by Borrero et al (Ref. 5), funded and directed by the MFD, updates the tsunami run-up heights for the San Francisco Bay. This study has found that the maximum run-up heights are significantly less than those provided in MOTEMS Table 31F-3-8. The entire text of this study is available on the MFD web site (Ref. 6).

b. Passing Vessel Forces on Moored Vessels

Another recent study (Ref. 7) completed by Professor David Kriebel at the US Naval Academy, further refines surge/sway loads from passing vessels on berthed vessels. The text is also available on the MFD web site (Ref. 6); Kriebel's modifications to earlier work by W. Seelig provide a more accurate determination of the forces on a moored vessel. The next code revision will recommend using this methodology, and will modify Section 3103F.5.5.

c. Multiple Mooring Hooks - Tie-down Capacity

Recently a question was asked regarding the tie-down of multiple mooring hook assemblies. MOTEMS specifies that the hooks must be able to withstand the minimum breaking load (MBL) of the strongest line, with a Safety Factor of 1.2. However, the MOTEMS does not provide guidance for multiple hooks and the required tie-down to the wharf deck. The following equation is being proposed for the MOTEMS (Section 3103F.10.1):

$$F_d = 1.2\ (MBL) \times [1 + 0.75\ (n-1)]$$

Where:

n = Number of hooks on the assembly

MBL = Minimum Breaking Load

F_d = Design lateral load for the tie-down into the wharf

Future Plans

We are currently considering an alternative to the strain-based performance standard of the MOTEMS. Professor Rakesh Goel, California State Polytechnic University, San Luis Obispo is working on this problem, using a drift-based criteria. The methodology is similar to the new FEMA 440 (Ref. 8), and we expect this work to be done by late 2007. After peer review and the usual public comment period, we will propose this change to the standards.

Summary and Conclusions

The MOTEMS is now an enforceable part of the California Building Code. Two California projects are already using the standards, and initial audits for high risk facilities are due in August 2008. Rehabilitation that is serious may require immediate repair, but in general, the engineering audit will provide a schedule for needed rehabilitation. The next update of the MOTEMS will have some significant changes, and a future update will contain an alternative to the structural strain-based performance as described in Section 7.

Acknowledgements

The author would like to thank members of the CSLC MFD engineering branch, including John Freckman, Avi Nafday, Hosny Hakim and Michael Edwards for their continuing efforts in the development and enforcement of the MOTEMS.

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