

# LIMITATIONS OF CURRENT U.S. DECOMPRESSION TABLES FOR CAISSON AND TUNNEL WORKERS

Raymond J. Roberge MD, MPH\*, Vern P. Anderson PhD<sup>s</sup>, Matt Gillen MS<sup>†</sup>

NIOSH - NPPTL Pittsburgh PA\*, NIOSH - EID Cincinnati OH<sup>s</sup>, NIOSH CSH, Atlanta GA<sup>†</sup>

## Objective

To describe the limitations of the current U.S. Decompression Tables utilized for caisson and tunnel workers at U.S. worksites.

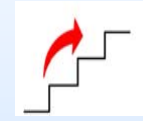
## Background

- 46 new tunnels are either under design or underway in the U.S. currently.<sup>1</sup>
- Caisson (water-tight structure within which construction is carried out under water) work and underground tunneling operations utilize compressed air to prevent seepage of water or to stabilize unstable soil conditions. This hyperbaric environment (ambient pressure and compressed air effects) exposes caisson and tunnel workers to the risks of decompression sickness (DCS).
- DCS, also called the "bends", is the result of inadequate decompression following exposure to increased pressure. DCS is related to intravascular or extravascular bubbles formed during reduction of environmental pressure (decompression). If the pressure is released too quickly, nitrogen gas is released in the body just like uncorking a bottle of soda, with the sudden expansion of carbon dioxide bubbles ("fizzing"). This can be very painful and sometimes fatal.
- The release of nitrogen bubbles into blood or tissues can result in obstruction of blood flow or pressure effects. Clinical manifestations of DCS include (but are not limited to) joint pain ("bends"), lytic lesions of bones (dysbaric osteonecrosis), cutaneous disorders (cutis marmorata), spinal cord and brain disorders (stroke, paralysis, paresthesias, bladder dysfunction, etc.), and cardiopulmonary disorders (shortness of breath ["chokes"]), arterial gas embolism).
- In order to prevent DCS, workers in hyperbaric environments must be safely brought back to the non-work environmental ambient pressure (decompressed) in decompression chambers.
- Decompression tables (generally) utilize stepwise (staged) progressions of gradually decreasing pressure at varying time intervals (based on work exposure pressures and length of work shift). The first decompression tables were developed by Haldane for the British Admiralty in 1908 and multiple other tables have since been developed.
- In 1971, the Washington State Decompression Tables that were used in multiple states became the federal code enforced by the Occupational Health and Safety Administration (OSHA) and remain, unchanged, as the decompression tables in force today.



## OSHA Decompression Tables Limitations

- The maximum worksite pressures allowed by OSHA and addressed by the OSHA decompression tables is 50 psi (~3.5 bar gauge).<sup>2</sup> However, because of the use of the modern Tunnel Boring Machine that consists of a large circular, rotating cutting head, many modern projects occur at greater depths than previously reached or require greater pressures due to digging in areas with more unstable soil conditions (e.g., the Lake Mead project may utilize pressures up to 14 bar gauge).
- The OSHA Decompression Tables use continuous (linear) decompression rather than the stepwise (staged) decompressions utilized in other industrialized nations. Continuous decompression is inefficient because the slow, continuous exposure to decreasing pressures allows the worker to continue to on-gas at the initial higher pressures and to spend lengthier times at low pressures that do not meaningfully suppress bubble formation.
- The breathing of oxygen during decompression has long been shown to be of value in decreasing decompression times and the incidence of DCS. Oxygen breathing during decompression is utilized in many industrialized nations, some of which (e.g., Germany) mandate its use, but OSHA does not allow the use of oxygen because of fire concerns.
- The OSHA tables use a single decompression schedule for all exposures "over 8 hours". This indicates that if a worker worked a double shift (16 hours), he would decompress on an "over 8 hour" schedule that is only slightly longer than the decompression time for an 8 hour shift, despite the fact that the exposure is a saturation exposure.



## NIOSH Decompression Research

- Due to an unacceptable rate of dysbaric osteonecrosis in workers from a tunnel job in Milwaukee<sup>3</sup> that took place between 1971-1973 utilizing pressures to 36 psi, the Undersea Medical Society undertook two workshops at the behest of NIOSH to address the feasibility of developing interim decompression tables.
- In response to NIOSH's request, computer-generated stepwise (staged) tables (Autodec III) were developed by Peter Edel, utilizing 15 years of commercial diving data. NIOSH issued a grant in 1980 to test these tables on human subjects that ultimately revealed the new tables to be inadequate and too lengthy to be commercially useful.
- As a result, another NIOSH grant was awarded to Eric Kindwall in 1980 to develop new stepwise (staged) decompression tables.

## Cont.

- Kindwall developed a variant of the Autodec III tables that incorporated the use of oxygen to shorten the times for decompression to a commercially acceptable length from 10 hrs. 46 min. to 3 hrs. 21 min. These new tables (Edel-Kindwall Caisson Tables) underwent both laboratory and field testing that indicated no evidence of DCS or dysbaric osteonecrosis at six months follow-up. These tables remain the only decompression tables to have been both laboratory and field tested.<sup>3</sup>
- In response to a 1985 OSHA request for comments on its existing Decompression Tables, NIOSH submitted the Edel-Kindwall Caisson Tables to OSHA, labeled as the "Criteria for Interim Decompression Tables for Caisson and Tunnel Workers", but they were not adopted (footnote 1).<sup>4</sup>
- An August 2, 1988 internal memo by Ralph Yodaiken, former medical director of OSHA, stated that "the OSHA tables have failed any reasonable test of adequate performance over the past 16 years...and oxygen decompression is long overdue in caisson work. The current OSHA tables are outdated and should be replaced in their entirety." Despite these concerns, the 1971 OSHA Decompression Tables remain in force today.<sup>4</sup>
- With the increase in deep tunneling operations at high pressures currently in the U.S., there is an urgent need to have up-to-date decompression tables that are able to adequately protect workers.
- OSHA/NIOSH are undertaking an evaluation of this situation and soliciting stakeholder input. OSHA has announced that it will consider using the next Standards Improvement Project (March, 2012) as a potential vehicle for updating the tables.

## Conclusions

- The OSHA decompression tables need to be updated to incorporate research findings.
- The Edel-Kindwall Caisson Tables are an improvement in the current OSHA tables, but still not adequate for dealing with pressures >50psi.
- Ongoing research will be needed to address decompression strategies in pressure environments >50 psi.
- Stakeholder input is an important component of addressing this issue.

## References

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(Footnote No. 1) OSHA Docket Office, Docket No. 5-009, NIOSH submission with cover letter form J. Donald Miller, MD, Director, NIOSH (7/12/1985)

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