**DEPARTMENT OF THE AIR FORCE**
**AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)**
**BROOKS CITY-BASE TEXAS**

11 June 2007

MEMORANDUM FOR USAF DENTAL EVALUATION & CONSULTATION SERVICE
DET 1 USAFSAM
GREAT LAKES IL 60088-5259

FROM: AFIOH/SDR
2350 Gillingham Drive
Brooks City-Base TX 78235-5103

SUBJECT: Consultative Letter, IOH-SD-BR-CL-2007-0100, Maximum Workloads for Dental Room with X-ray Pass Through Unit

1. Summary: On 1 June 2007, Dr. Gregory C. Browning, Director of Dental Facility Design, USAF Dental Evaluation and Consultation Service requested support from the Air Force Institute of Operational Health, Radiation Surveillance Division (AFIOH/SDR) for a shielding evaluation regarding the installation of pass-through x-ray cabinets between adjacent intraoral x-ray rooms. A pass through x-ray cabinet allows the x-ray tube to be passed through the wall of two adjacent x-ray examination rooms, permitting the same machine to be used in both rooms. The customer requested calculation of maximum workload (exposures/week) allowed for three different scenarios for a digital radiography unit and an E speed film unit. For the purpose of this report an exposure is one x-ray shot.

The results of these calculations (specified in NCRP 145) indicate additional shielding of the pass-through x-ray cabinet will be needed if the workload could be expected to be greater than 140 exposures/week for the E-speed film unit or 376 exposures/week for the digital radiography unit. As acknowledged by the customer, the results given in this report will be used as a conservative benchmark for purchasing considerations only. The customer provided a generic conservative room design that is not specific to any particular dental facility. Specific base installation will require coordination with the local Bioenvironmental Engineering shop and include evaluation of the actual room dimensions, tube placement, and tube operating parameters. Upon request, AFIOH/SDRH can provide further shielding analysis and calculations.

2. The three different scenarios requested by the customer are:

a. Two thicknesses of 5/8 in. gypsum wallboard, giving a total thickness of 1.25 in. (3.2 cm). This is the wall thickness of the treatment room with no cabinet.

b. A single cabinet door without lead lining. The cabinet door construction consists of 5/8 in. thick particle board (45 lb/ft$^3$) with 1/32 in. laminate on each side. For calculation purposes this was assumed to be equivalent to a 5/8 in. (1.6 cm) thickness of wood.

c. A single cabinet door with 0.016 in. (0.41 mm) of lead lining.

3. NCRP report No. 145 *Radiation Protection in Dentistry* provides recommendations for dental facility shielding goals. The recommended shielding goal is dependent on the classification of the area of concern as controlled or uncontrolled. The adjacent x-ray room was classified as controlled since patient access to this area is restricted. The shielding goal for a controlled environment is 0.1 mGy/wk. This shielding goal is one tenth of the annual exposure limit of 0.05 Sv (5 rem) for the occupational worker. As a result, a barrier that meets a shielding goal of 0.1 mGy/wk also protects the pregnant worker to her pregnancy term limit of 0.005 Sv (0.5 rem). Additional information may be found in section C.1.1.2 of NCRP 145.

4. A conservative room layout provided by the customer is given in Appendix A. The treatment room is narrow in width with casework cabinets on one side, causing the patient chair to be closer to the x-ray cabinet. The distance to the occupational worker is 12 in. (30 cm) from the wall as recommended by NCRP No. 145. As specified by the customer, the occupational worker is approximately 30 in. (76 cm) closer to the x-ray tube than the patient in the adjacent room. As a result of the worker's closer proximity to the tube combined with an occupancy factor twenty times greater for the worker (1/20 for the patient compared to 1 for the worker), protection of the occupational worker was determined to be the limiting factor for maximum workload.

5. The following are the given x-ray tube parameters and additional input variables needed for calculation of primary wall shielding; all are specified as being conservative.

| | Digital Radiography | E speed Film |
|---|---|---|
| max operating potential, $V_t$ | 66 kVp | 70 kVp |
| tube amperage | 8 mA | 7 mA |
| exposure time | 0.125 sec | 0.333 sec |
| occupancy factor [1], T | 1 | |
| distance (tube to worker) | 2.08 m (6.83 ft) | |
| use factor[2], U | 0.4 (side wall) | |
| transmission factor[3], α | 0.095 | |

6. The equations used for the calculations of maximum allowable exposures per week can be seen in Appendix B of this document. A significant assumption necessary for the calculations is

[1] The occupancy factor of 1 is based on the very conservative assumption that the area being shielded is always being occupied by the same occupational worker.
[2] The use factor is the fraction of the total "ON" time that the x-ray tube is directed toward the wall. Values are given in Table F.2 of NCRP 145 Appendix F for intraoral machines.
[3] The patient transmission factor takes into account the fact that the patient and the image receptor diminish the beam intensity. This value depends on the kVp and was derived from NCRP 145 Appendix F Fig F.4, a graph of measured transmission factors through the typical patient for varied kVp bitewing exposures.

that the particle board cabinet door has an x-ray transmission comparable to that of an equal thickness of wood. A discussion with the customer confirmed that this was an appropriate assumption.

7. Calculation Results: Results of the requested scenarios are provided in the table below:

| **Scenario** | **MAXIMUM ALLOWABLE WEEKLY EXPOSURES** | |
|---|---|---|
| | **Digital radiography** | **E-Speed Film** |
| 1.25" gypsum wallboard (two thicknesses of 5/8") | 2,453 | 924 |
| Single cabinet door without lead lining | 376 | 140 |
| Single cabinet door with 0.016" (0.4mm) lead lining | 55,903 | 21,065 |

8. Recommendation: Additional cabinet door shielding is needed if workload could be expected to exceed 140 exposures/week for the E-speed film unit or 376 exposures/week for the digital radiography unit.

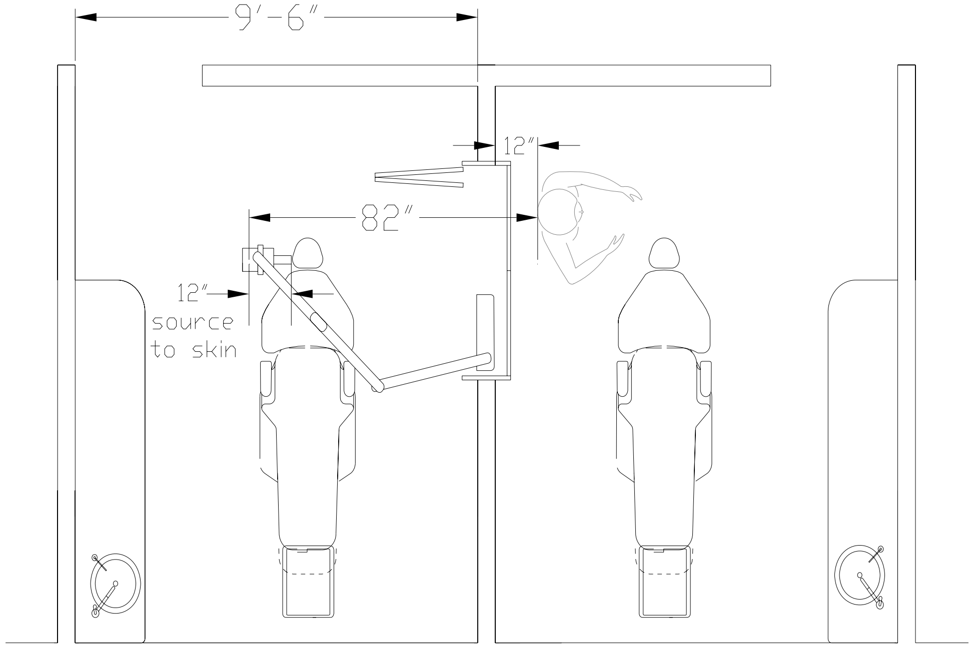
9. If you have any further questions regarding this report, please contact 2nd Lt Vivien Miller at DSN 240-5364 or vivien.miller@brooks.af.mil. Please direct any questions or comments regarding Radiation Surveillance Division support to the division chief, Lt Col Kevin Martilla at 210-536-5565 (DSN: 240-5565) or kevin.martilla@brooks.af.mil.

//signed//

VIVIEN J. MILLER, 2nd Lt, USAF, BSC
Operational Health Physics Consultant

Attachments:
1. Room Layout
2. Shielding Equations

Attachment 1:  Room Layout




**Notes:**

Treatment room width shown is one of the narrower rooms with single-sided casework which pushes chair closer to x-ray cabinet.

12" source to skin "cone length"

12" wall to occupant distance as allowed by NCRP 145.

Attachment 2: Shielding Equations

Equation 1: This equation calculates the air kerma per unit workload, $K_w$ in the primary beam at 1m from the continuous phase x-ray tube at an operating potential $V_t$. The equation is derived from data taken from equipment typical of diagnostic radiology and is only valid in the range of 50 to 150 kVp. It is equation F.9 in appendix F, NCRP report 145.

$$K_w = 1.222 - (5.664\text{X}10^{-2})V_t + (1.227\text{X}10^{-3})V_t^2 - (3.136\text{X}10^{-6})V_t^3$$

Equation 2: Barrier transmission is calculated for each scenario. This equation requires the use of the parameters $\alpha, \beta$, and $\gamma$. These parameters are characteristic of the barrier material, the waveform, and the operating potential. These parameters can be found for various materials in Table F.4b of NCRP report 145. The following equation is equation F.4.

$$B = \left[\left(1 + \frac{\beta}{\alpha}\right)\exp(\alpha\gamma x) - \frac{\beta}{\alpha}\right]^{\frac{-1}{\gamma}}$$

Equation 3: The maximum workload is found by solving Equation F.16 of NCRP report 145 for the quantity of exposures/week. The variables, excluding $K_w$ which is solved for using Equation 1, are as specified in the table of section 5. of this document.

$$\text{exposures/week} = \frac{Pd^2}{BK_w \alpha UT(mA\min)}$$

where $mA\min$ equals the product of exposure time (minutes) and tube amperage (mA).

Since equation 3 only accounts for primary beam radiation only, $K_w$ was increased by 10 percent as recommended by NCRP 145 to account for leakage and scattered radiations that result from the fraction of the beam that is not oriented towards the primary barrier.