Procedure for Solving Missing Factor Problems using the Density Maintenance Formula

Questions 1-5 on the monthly exam

<table>
<thead>
<tr>
<th>Old exposure set</th>
<th>New exposure set</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mA</td>
<td>200 mA</td>
</tr>
<tr>
<td>.12 sec</td>
<td>___ sec</td>
</tr>
<tr>
<td>72 kVp</td>
<td>60 kVp</td>
</tr>
<tr>
<td>400 Film/Screen Speed</td>
<td>300 Film/Screen Speed</td>
</tr>
</tbody>
</table>

The missing factor problem was developed to teach students how to adjust their exposure technique in a clinical setting. Examples of this would include changing to a shorter exposure time in order to prevent motion, or a change in distance on a mobile radiographic exam. These complex problems help prepare the student for density maintenance problems on the registry exam and to adjust for varying factors in the clinical setting.

The following formula can be memorized by the students. Once this formula is memorized, the student only needs to substitute in the appropriate values to solve the equation.

\[
\text{mAs}_2 = \text{mAs}_1 \times \frac{\text{New Distance}^2}{\text{Old Distance}^2} \times \frac{\text{New Grid}}{\text{Old Grid}} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}}
\]

A sample problem is provided on the next page to explain the calculation of these problems.
Density Maintenance Problems
Questions 1-5 on the monthly exam

The missing factor type of problem was developed and is utilized to provide a situation to a student that could be applicable in a clinical setting. An example of this would be an adjustment for a shorter exposure time in order to prevent motion or a change in distance on a mobile radiographic exam. If a student is able to work these complex problems, they should be able to handle any Density Maintenance Problems on the registry exam and should know how to adjust for varying factors in the clinical setting.

The following formula can be memorized by the students. The only difficult part to remember is that distance and grids are new over old, and kVp and Film/Screen are old over new.

\[
\frac{\text{mAs}_2}{\text{mAs}_1} = \frac{\text{New Distance}^2}{\text{Old Distance}^2} \times \frac{\text{New Grid}}{\text{Old Grid}} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}}
\]

A sample problem is provided to explain the calculation of these problems.

**Sample Problem**

Determine the missing factor that will produce the same density as the original set of exposure factors.

**Old exposure set**
- 200 mA
- .07 sec
- 80 kVp
- 200 Film/Screen Speed
- 72" SID
- 8:1 Grid

**New exposure set**
- 300 mA
- ___ sec
- 70 kVp
- 400 Film/Screen Speed
- 42" SID
- 12:1 Grid

The values of the problem above will be inserted into our formula. Each step will be discussed as the values are replaced.

\[
\frac{\text{mAs}_2}{\text{mAs}_1} = \frac{\text{New Distance}^2}{\text{Old Distance}^2} \times \frac{\text{New Grid}}{\text{Old Grid}} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}}
\]

**Step 1: Calculation of mAs₁**

Calculate mAs₁ by multiplying the original mA and the original time.

\[
m\text{As}_1 = 200 \text{ mA} \times 0.07 \text{ sec}.
\]
\[
m\text{As}_1 = 14
\]
This value is placed in our formula.

\[
\frac{\text{mAs}_2}{14} = \frac{\text{New Distance}^2}{\text{Old Distance}^2} \times \frac{\text{New Grid}}{\text{Old Grid}} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}}
\]

**Step 2: Inserting Distance Values**
The new distance in our sample problem is 42.
The original distance is 72
These values are placed in our formula

\[ mAs_2 = 14 \times \frac{42^2}{72^2} \times \frac{\text{New Grid}}{\text{Old Grid}} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}} \]

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### Step 3: Inserting Grid Values

Values are assigned for the various grid ratios. The following chart demonstrates the values that are used for these problems.

<table>
<thead>
<tr>
<th>Grid Ratio</th>
<th>Grid Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:1</td>
<td>6</td>
</tr>
<tr>
<td>12:1</td>
<td>5</td>
</tr>
<tr>
<td>8:1</td>
<td>4</td>
</tr>
<tr>
<td>6:1</td>
<td>3</td>
</tr>
<tr>
<td>5:1</td>
<td>2</td>
</tr>
<tr>
<td>non-grid</td>
<td>1</td>
</tr>
</tbody>
</table>

The grid factor for a 12:1 grid is 5
The grid factor for a 8:1 grid is 4
These values are placed in our formula.

\[ mAs_2 = 14 \times \frac{42^2}{72^2} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}} \]

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### Step 4: Inserting the kVp factors

Values are assigned to the various kVp levels
The lowest kVp setting is considered our base kVp and gets assigned a value of 1
Any kVp value that is approximately 15% greater than our base kVp is assigned a value of 2
Any kVp value that is approximately 30% greater than our base kVp is assigned a value of 4

The old kVp value in our sample problem becomes 2.
The new kVp value in our sample problem becomes 1.
These values are placed in our formula.

\[ mAs_2 = 14 \times \frac{42^2}{72^2} \times \frac{\text{Old kVp factor}}{\text{New kVp factor}} \times \frac{\text{Old Film/Screen Speed}}{\text{New Film/Screen Speed}} \]

---

### Step 5: Inserting the Film/screen factors

The old film/screen value in our sample problem is 200.
The new film/screen value in our sample problem is 400.
These values are placed in our formula.

\[
m_{As_2} = 14 \times \frac{42^2}{72^2} \times \frac{5}{4} \times \frac{2}{1} \times \frac{200}{400}
\]

Step 6: Solving for mAs\(_2\)

\[
m_{As_2} = 14 \times \frac{42^2}{72^2} \times \frac{5}{4} \times \frac{2}{1} \times \frac{200}{400}
\]

A calculator should be used at this point to solve the problem.

\[
m_{As_2} = 14 \times 42 \times 42 \div 72 \div 72 \times 5 \div 4 \times 2 \times 200 \div 400
\]

In our sample problem \(m_{As_2} = 5.98\)

Step 7: Solving for the final answer

In our sample problem we just determined the value of \(m_{As_2}\). The problem is looking for the new exposure time.

<table>
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<tr>
<td>.07 sec</td>
<td>___ sec</td>
</tr>
<tr>
<td>80 kVp</td>
<td>70 kVp</td>
</tr>
<tr>
<td>200 Film/Screen Speed</td>
<td>400 Film/Screen Speed</td>
</tr>
<tr>
<td>72&quot; SID</td>
<td>42&quot; SID</td>
</tr>
<tr>
<td>8:1 Grid</td>
<td>12:1 Grid</td>
</tr>
</tbody>
</table>

To solve this last step we use the formula \(mAs = mA \times \text{time}\)

5.98 mAs\(_2\) = 300 mA \times \text{time}

\[
\text{time} = \frac{5.98}{300}
\]

\[
\text{Time} = .02 \text{ seconds}
\]
Greatest Density Problems

The method that is described on the flowing pages is a system for calculating greatest density based on the multiplication of conversion factors. A sample problem is utilized to explain this system.

**Sample Problem**

A. 200 MA .3 36" SID 62 kVp 400 film/screen speed 8:1 grid
B. 200 MA .25 32" SID 70 kVp 200 film/screen speed 5:1 grid
C. 300 MA .25 42" SID 82 kVp 100 film/screen speed 6:1 grid

Step 1: Distance

The first step is to deal with the varying distances. The method we use is to convert all of the distances into a relationship of new distance squared over old distance squared. We use the shortest SID as our new distance for these problems.

**Convert all to base SID**

A. 36" becomes $\frac{32^2}{36^2}$
B. 32" becomes $\frac{32^2}{32^2}$
C. 42" becomes $\frac{32^2}{42^2}$

A. 200 MA .3 $\frac{32^2}{36^2}$ 62 kVp 400 film/screen speed 8:1 grid
B. 200 MA .25 $\frac{32^2}{32^2}$ 70 kVp 200 film/screen speed 5:1 grid
C. 300 MA .25 $\frac{32^2}{42^2}$ 82 kVp 100 film/screen speed 6:1 grid
Step 2: kVp

Values are assigned to the various kVp levels
The lowest kVp setting is considered our base kVp and gets assigned a value of 1
Any kVp value that is approximately 15% greater than our base kVp is assigned a value of 2
Any kVp value that is approximately 30% greater than our base kVp is assigned a value of 4

In our sample problem:
62 kVp becomes 1
70 kVp becomes 2
82 kVp becomes 4

A. 200 MA \( \frac{32n^2}{36n^2} \) 62 (1) 400 film/screen speed 8:1 grid

B. 200 MA \( \frac{32n^2}{32n^2} \) 70 (2) 200 film/screen speed 5:1 grid

C. 300 MA \( \frac{32n^2}{42n^2} \) 82 (4) 100 film/screen speed 6:1 grid

Step 3: Grid Ratios

Values are assigned for the various grid ratios. The following chart demonstrates the values that are used for these problems.

\[
\begin{array}{c|c}
\text{Grid Ratio} & \text{Value} \\
16:1 & 6 \\
12:1 & 5 \\
8:1 & 4 \\
6:1 & 3 \\
5:1 & 2 \\
\text{non} & 1 \\
\end{array}
\]

Because grids will decrease the density of the film, we will be dividing by this grid factor in our last step.

A. 200 MA \( \frac{32n^2}{36n^2} \) 62 (1) 400 film/screen speed 8:1 grid \( \div 4 \)

B. 200 MA \( \frac{32n^2}{32n^2} \) 70 (2) 200 film/screen speed 5:1 grid \( \div 2 \)

C. 300 MA \( \frac{32n^2}{42n^2} \) 82 (4) 100 film/screen speed 6:1 grid \( \div 3 \)
Step 4: Final Density Value

In our last step do the calculations to determine a final density value for each set of exposures.

A. 200 MA .3 \( \frac{32^{n^2}}{36^{n^2}} \) 62 (1) 400 film/screen speed 8:1 grid  ÷ 4

B. 200 MA .25 \( \frac{32^{n^2}}{32^{n^2}} \) 70 (2) 200 film/screen speed 5:1 grid  ÷ 2

C. 300 MA .25 \( \frac{32^{n^2}}{42^{n^2}} \) 82 (4) 100 film/screen speed 6:1 grid  ÷ 3

\[
\begin{align*}
A &= 200 \times 0.3 \times 32 \times 32 \div 36 \div 36 \times 1 \times 400 \div 4 \\
B &= 200 \times 0.25 \times 1 \times 2 \times 200 \div 2 \\
C &= 300 \times 0.25 \times 32 \times 32 \div 42 \div 42 \times 4 \times 100 \div 3
\end{align*}
\]

A = 4,741
B = 10,000
C = 5,805

Sample Problem

A. 200 MA .3 36" SID 62 kVp 400 film/screen speed 8:1 grid
B. 200 MA .25 32" SID 70 kVp 200 film/screen speed 5:1 grid
C. 300 MA .25 42" SID 82 kVp 100 film/screen speed 6:1 grid

The answer would be "B"