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CORRECTIVE ACTION TESTING FOR LIGHT VEHICLE OBSCURATION SMOKE SYSTEM (LVOSS) M90 GRENADE

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SMOKE/OBSCURANTS OFFICE

August 2000

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This report documents the corrective action test that was conducted to determine the root cause(s) for short-range failures of the M90 grenade in cold temperatures (-50°F).

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PREFACE

The work described in this report was authorized under Project No. 50910, Engineering Development. The work was started in March 1999 and completed in August 1999.

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FIGURE

TABLES

CORRECTIVE ACTION TESTING
FOR LIGHT VEHICLE OBSCURATION SMOKE SYSTEM (LVOSS)
M90 GRENADE

1. **PURPOSE OF TEST.** The purpose of this test was to determine the root cause(s) for short-range failures of the M90 grenade in cold temperatures (-50°F) and to correct the problem.

2. **SCOPE OF THE TEST EFFORT.** The information for this test report is based on corrective action testing conducted at Pine Bluff Arsenal (PBA) from 25 Mar 99 to 4 Aug 99. The testing was conducted to determine the cause of grenade failures discovered during first article testing at PBA and Production Verification Testing at Dugway Proving Ground. The manufacturer, PBA, teamed with PM Smoke to investigate the problem, recommend a corrective action, and fix the problem.

3. **SYSTEM DESCRIPTION.*** The LVOSS is a self-defense smoke obscurant system which is externally mounted on light vehicles, primarily the high-mobility multipurpose wheeled vehicle (HMMWV), in units whose mission places them at greater risk of engagement from enemy direct and indirect fire weapons and weapon systems.

a. The LVOSS consists of one arming/firing unit (A/FU); a wiring harness, mounting brackets and hardware, one to four M7 dischargers with elevation brackets, and the M90 smoke grenade. The LVOSS components are integrated as a complete system that is operated from within the vehicle via the A/FU.

b. The plastic M7 discharger, based on the design of the fielded M257 discharger, has four 66mm tubes. It can be mounted at five different locations on a vehicle; the four corners of the roof for the HMMWV variants (M1025/1026 and M1114), or a single discharger mounted on the turret ring of the M966.

c. The M90 grenade (**Figure**) is part of the LVOSS, and is integrated with the other LVOSS components to form a complete system. The M90 grenade is a soft-launched, nonfragmenting, pyrotechnic smoke dispenser. The grenade includes three individual dual-ported, core-burning teraphthalic acid-based smoke canisters that are ejected by a charge of black powder. The female connector at the base of the grenade completes the firing circuit and holds the grenade on the male electrical connector at the base of the discharger tube. To fire the grenade, the AF/U is armed and, when the firing button(s) is (are) pushed, the firing circuit directs electrical energy from the vehicle's batteries to the electric match inside the propulsion base. The electric match ignites and the flame and

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* Formal Test Report for the Production Verification Test (PVT) of the LVOSS, M7 Discharger, M305 and M304 Installation Kits, and M90 Smoke Grenade, July 1999,TECOM Project No. 1-WE-300- LVS-012

hot slag in turn ignites the black powder lifting charge. The expanding gases eject the three smoke canisters while simultaneously lighting them via starter patches in each canister.

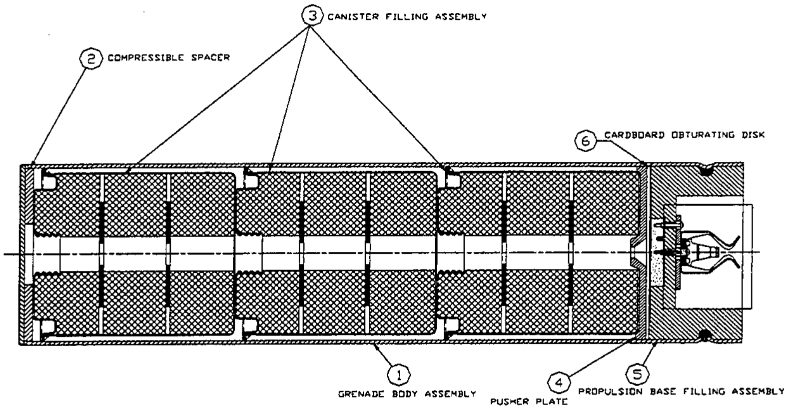

Figure: GRENADE, LAUNCHER, ASSEMBLY

The smoke canisters produce white smoke for about 13 seconds and travel to an average distance of 35 ± 5 meters.

4. TEST AND EVALUATION. The components, which were tested and evaluated as part of the Corrective Action Test, are:

- The Grenade Launcher Assembly,
- The Compressible Spacer,
- The Smoke Canister,
- The Pusher Plate,
- The Propellant Retainer Assembly,
- The Black Powder,
- The Base, and
- The Obturating Disk

For a summary of the test results refer to Attachment 1.

4.1 GRENADE-LAUNCHER ASSEMBLY (DWG #: 13-19-802). The functions of the tube and end cap are to protect the internal items from handling abuse and exposure to the environment; constrain the expanding propulsion gases in the launch direction and allow the smoke submunitions to launch from the tube without interference.

TABLE 1: Results of Tube/Cap Assemblies Tested

TEST TEMP	CONFIGURATION (TUBE / END-CAP)	RESULTS
-50°F	Lewis Produced & Painted / Lewis Crimped & Painted	Base Line. 1.25 g, Class IV Black Powder
-50°F	Bare Tube / Lewis Crimped Cap	No improvement
-50°F	Anodized Tube / Lewis Crimped Cap	Fixed the problem
-50°F	Green Paint Only/ Lewis Crimped	There is an improvement, But does not fix the problem
-50°F	Black Paint Only/ Lewis Crimped & Painted	No improvement
-50°F	PEL / PEL End Caps	Marginal improvement
-50°F	Lewis Produced & Painted / PEL Re-crimped	Some improvement
-50°F	Lewis Produced / PEL 1500 psi	No improvement
-50°F	Lewis Produced / PEL 2500 psi	No improvement
-50°F	Lewis Produced / Lewis 3000 psi	Made it worse
-25°F	Bare Tube / PEL Crimped	Improved. Amount of black powder increased to 1.33g, class IV

Different combinations of the tube/cap assembly were prepared and tested as shown in **Appendix A.** Assemblies were produced either by Lewis Engineering or by PBA's Production Engineering Laboratory (PEL). The production configuration, labeled in **Table 1** as Lewis produced tube/Lewis crimped and painted cap, was used as a base line for side by side comparisons with 10 other combinations under cold temperature conditions.

The focus of the end cap and tube testing was on the differences, if any, in the end cap crimp pressure, and also on stages in the finishing and painting process. Reducing the crimp pressure on the cap improved the results, and increasing its pressure made the results worse. Also, the painting process appeared to reflect the results. Tubes that were solely anodized or only had their bottoms painted green (no paint over the end cap) showed improvement, whereas all other configurations showed no improvement. Re-crimping the end cap also indicated potential for grenade performance improvement, but was not enough to correct the cold failures.

4.2 COMPRESSIBLE SPACER (DWG #: 13-19-804). The compressible spacer ensures the smoke canisters are held tightly in the grenade body and also enhances ignition reliability by providing extra volume for flame front advancement. During the test, 3/4" and 1/2" (in 8 grenades only) spacers were used (**Appendix A and Table 3**). Use of the same 1/2" spacer used in development showed no improvement.

TABLE 2: Results of Compressible Spacers Tested

TEST TEMP	SPACER	RESULTS
-25°F & -50°F	¾ inch	Base line
-50°F	½ inch	No improvement

4.3 SMOKE CANISTER (DWG #: 13-19-810). The function of this component is to produce white smoke. When fired from the LVOSS discharger, the canisters reach a maximum height of 10 m and travel an average distance of 35 ± 5 m at ambient conditions. They travel shorter distances under cold conditions and longer distances under hot conditions. They burn approximately 12–13 seconds. Duration of the cloud is dependent on the meteorological conditions.

One of the suspected causes of the cold temperature failure was oversized canisters. A ring gauge, installed on the smoke canister production line, was used to provide a 100% inspection of all completed smoke canisters. Even after screening the canisters to weed out oversized ones, the short ranges occurred. The oversized canister that was intentionally used did not, by itself, cause the short ranges.

4.4 PUSHER PLATE (DWG NO: 13-19-803). One function of the pusher plate is to catch expanding gases generated by the black powder and to push the smoke canisters out of the grenade tube. The other function is to channel a sufficient amount of flame through the column of canisters to assure ignition of the igniter patches. Two different sources, Lewis Corporation and PBA's Directorate of Public Works Craft Shop produced the Pusher Plates. Lewis produced pusher plates came in at three different sizes: 2.470", 2.475", and 2.483" diameter (all anodized) (**Appendix A and Table 3**). The Pine Bluff Arsenal produced plate was not anodized. There was a concern about the pusher plate binding to the aluminum grenade tube.

TABLE 3: Results of Pusher Plates Tested

TEST TEMP.	PUSHER PLATE DIAMETER	RESULTS
-25°F/-50°F	2.475in (Production item)	Base line
-50°F	PEL Plate (2.475")	No improvement
-50°F	2.470 in	Made it worse
-50°F	2.483 in	Pusher plate fixed the problem

The idea of a smaller diameter pusher plate (2.470") was entertained in order to eliminate the problem. Test results, however, showed that it increased the problem. The oversized pusher plate (2.483"), on the other hand, fixed the problem. The side by side comparison of test results pointed thoughts towards a possible "blow-by" problem (i.e. gases were going around the plate instead of pushing the plate) when the normal diameter plate was used. This led the studies to search for a suitable obturating material.

4.5 PROPELLANT RETAINER ASSEMBLY (DWG #: 13-19-812). The function of the propellant retainer assembly is to hold the black powder in the base until the time of firing, and to burn through immediately to facilitate grenade launch and ignition. The assembly is prepared by sandwiching 3M series #810 tape between two layers of aluminum tape. During development, one piece of 1" 3M 810 tape was used in the propellant retainer assembly.

TABLE 4: Results of Propellant Retaining Assembly Tested

TEST TEMP.	TAPE	RESULTS
-50°F	1.5 inch	Base line
-50°F	1.0 inch	No improvement

During production a single 1.25" piece of Magic tape was used to simplify manufacture of the item. Both configurations were tested, and no differences were observed.

4.6 BLACK POWDER. The black powder is used to light and expel the canisters. Black powder was investigated as a possible cause for the cold temperature problem. Different lots of black powder from two different production sites were evaluated and tested (**Appendix A and Table 5**). The development black powder (LOT#: 93F78-56-1), performed consistently better than the production black powder (LOT #: 99A78-69-1). Both lots were Class IV material, and the only apparent difference was their place of manufacture. The development lot was made by GOEX in Louisiana, and the production lot was made by GOEX in Pennsylvania. The Class V powder that has a smaller particle size was tested for side by side comparison with the Class IV.

The black powder with small particle size and large surface area (class V) should theoretically provide better burning power than the large particle size (class IV), but the test results showed no improvement over the large particle size. The amount of black powder used in each configuration varied. The evaluation of the smaller powder quantities (0.75g, 0.9g, 0.95g, 0.97g) were excluded from this discussion and were incorporated in section 4.8 since their performance is tied to the obturating disk. The moisture content of the black powder is one of the important factors for the overall performance of the grenade. Test results from 28 Jun 99 were anomalous and the cause of the problem was humidity control equipment that was out of order. It is unknown how long the equipment had been malfunctioning and what impact that had on the entire corrective action test series. Continuous monitoring of the humidity, during black powder loading, was implemented as a correction.

TABLE 5: Results of Black Powders Tested

TEST TEMP.	PRODUCTION POWDER (Class IV)	AMOUNT (g)	RESULTS
-50°F	99A78-69-1	1.25	Base line
-50°F	99A78-69-1	1.23	No improvement
-25°F	99A78-69-1	1.33	Fixed the problem in combination with PEL produced unfinished tube
-50°F	99A78-69-1	1.34	Marginal improvement
-25° & -50°F	99A78-69-1	1.35	No improvement
-50°F	99A78-69-1	1.38	Some improvement
	DEVELOPMENT POWDER (Class IV)		
-50°F	93F78-56-1	1.25	Some improvement
-50°F	93F78-56-1	1.31	Some improvement
-50°F	93F78-56-1	1.38	Some improvement. May introduce long range problem
	98F79-58-1 (Class V)		
-50°F	98F79-58-1	1.29	Marginal improvement
-50°F	98F79-58-1	1.32	No improvement
-25°F	98F79-58-1	1.35	No improvement
	GOEX 78-28	1.34	No improvement

4.7 BASE. The major functions of the base are to complete the firing circuit, keep the grenade sealed against water penetration, hold the grenade in the discharger, contain the propulsion charge, and shunt any electrical discharge away from the black powder.

During development of the grenade, the ground shunt periodically caused the aluminum tape to peel up and result in a non-firing grenade. This was not a problem in production, but was investigated anyway by using bases with the ground shunts removed.

Some of the bases were leak-tested by the manufacturer for quality assurance. The pyrotechnic match head was exposed to water. While a difference in performance was noted (mainly shorter ranges), extremely short-range failures were not attributed to this process. After this test, the Quality Assurance requirements were changed since exposure of pyrotechnics to moisture is considered a bad practice.

Table 6: Results of Bases Tested

TEST TEMP.	BASE	RESULT
32°,0°,-25°,-50°F	With Ground Shunt	No improvement
-50°F	Without Ground Shunt	No improvement
-50°F	Leak Tested With Shunt	No improvement

4.8 OBTURATING DISK (Doc No: 13-19-826). The function of this component is to prevent gases from going around the pusher plate. It is placed between the pusher plate and the base so the gases will hold the disk against the pusher plate during launch. Two different types of paper, thin (oil-based) and thick (non-oil- based), were used and evaluated. The disks were tested at hot (160°F), standard ambient (77°F ± 18°F), and two different cold (-25°F, -50°F) conditions. All the items with the exception of black powder quantity and disk thickness were kept identical for the -50°F test (**Appendix A**). The configuration with the thick paper-obturating disk performed better than the thin paper option at -50°F (19 Jul 99 and 2 Aug 99). Based on the tests performed, the obturating disk improved the cold temperature performance as shown in the **Appendix C**. The improvement is noticeable when these results were compared side by side with the studies carried out without obturating disk (**Appendix B**).

Table 7: Results of Obturating Disks Tested

TEST TEMP.	OBTURATING DISK	RESULT
-50°F	Thin paper	No improvement
-25°F & -50°F	Thick paper	Fixed the problem. Used 0.90g of powder @ -50°F & 0.97g powder @-25°F

5. CONCLUSION.

a. Grenades that were built with an anodized only tube (no paint) performed better than others built with tubes without anodizing process or tubes that were fully painted. This was not a satisfactory solution to the problem, since a painted tube was one of the requirements of the grenade.

b. Studies showed the foam spacer performed as expected and did not contribute to the short-range failures.

c. Test results proved that oversized canisters did not cause the short-range problem.

d. No differences in grenade performance were attributed to the propellant assembly.

e. Selection studies of the black powder proved the particle size, amount, and moisture content are important factors for the performance of the grenade. Studies were carried out by utilizing two different particle size black powders, Class IV and Class V. Test results showed the difference between the two for the M90 grenades were negligible.

f. The propulsion base did not contribute to the cold temperature grenade failures.

g. Three different sizes of pusher plates were evaluated. An oversized plate (2.483") fixed the cold temperature problem, but led to concerns about interference and binding with the tube wall. The production pusher plate (2.475" OD) continued to be used, but an obturating disk was incorporated to prevent gases from going around the pusher plate. A 0.090" thick paperboard was selected, and this solved the cold temperature problem for the M90 smoke grenade.

Appendix A

Corrective Action Hardware Matrix

Appendix A

Component			25-Mar-99	31-Mar-99	08-Apr-99	12-Apr-99		15-Apr-99		19-Apr-99					20-Apr-99			26-Apr-99			28-Apr-99			30-Apr-99			01-May-99			05-May-99		06-May-99		07-May-99		13-May-99				15-May-99		24-May-99		28-May-99		07-Jun-99	09-Jun-99	10-Jun-99	15-Jun-99	17-Jun-99	21-Jun-99		22-Jun-99	24-Jun-99	28-Jun-99				01-Jul-99				09-Jul-99		13-Jul-99			19-Jul-99		20-Jul-99	26-Jul-99	27-Jul-99	02-Aug-99	04-Aug-99
Base																																																																										
	With Ground Shunt		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Without Ground Shunt																								X																																																		
	Leak Tested with Shunt																																																																						X				
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		1.23 g	X	X		X		X		X	X				X			X	X	X	X			X	X																																																				
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		1.38 g													X																																																											
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Tape																																																																										
	1" wide Magic Tape																X																																																									
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Pusher Plate																																																																										
	2.470"	Lewis																							X																																																
	2.475"	*Lewis*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X		X	X	X	X	X	X	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
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	None		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X							X
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Smoke Canister																																																																										
	PBA Production		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PEL																																																																									
Aluminum Tube																																																																										
	Lewis Produced and Painted		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X	X					X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	Reseamed											X																																																														
	Bare Tubes																													X																																X												
	Anodized Tubes																														X			X	X																																								
	Green Paint Only																																			X																																					
	Black Paint Only																																						X																																		
	Air Dry																																				X																																				
	PEL																									X			X												X																																
End Cap																																																																										
	Lewis Crimped and Painted		X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X		X	X				X	X				X		X	X		X	X		X		X	X	X	X		X	X						X		X		X	X	X	X	X	X	X	X	X	X	X	X
	Lewis Crimped																													X	X			X	X	X																																					
	PEL Crimped																																																														X													
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	Lewis 1500 psi																																																								X																		
	PEL 2500 psi																																																						X																				
	Lewis 3000 psi																																																							X																			
	No End Cap												X					X																									X																															
	No RTV																																					X																																				
	PEL End Caps																									X			X												X				X																												
Spacer																																																																										
	3/4" Spacer		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	1/2" Spacer																				X																																																						
Results																																																																										
	Hot	*160 F*		■		■	■			■																				1													■	■		■				■	■							■			■																		
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	Cold																																																																									
		-50 F		■		■	■	■	■		■	1	■	2	■	■	■	8			■	4	■	■	■	4	■		5	■	■	■	■	■	■	3	■	■	■	1	■		■	2	1	■		■	1	■	2	1		■	■	■	■											■	1	2	■		■	
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		0 F																		■																																																					
		32 F																		■																																																				■

Yellow indicates that at least one of the grenades had a canister that out of specification. For hot this was beyond 50 meters, for ambient it was beyond 40 meters, and for cold it was less than 20 meters but greater than 10 meters

Numbers in the boxes refer to the number of grenades that failed, not to the number of canisters.

Appendix B

Cold Temperature Test
Poor Results

Appendix B

COLD TEMPERATURE FUNCTIONING AFTER LOOSE CARGO VIBRATION

4.3.6.2.3	Pre-Cond Temp Cold (50 degs F for 24 hrs)		Loose Cargo for 10 minutes each axis at -50 degs F		Pre-Cond Temp Cold (-50 degs F for 24 hrs)	
Group #	Start Time/Date	Finish Time/Date	Start Time/Date	Finish Time/Date	Start Time/Date	Finish Time/Date
#1-4	0721/3-24-99	0900/3-25	0903/3-25-99	0923/3-25-99	1600/3-27-99	250/3-31-99
#9-12	0721/3-24-99	0900/3-25	0903/3-25-99	0923/3-25-99	1600/3-27-99	250/3-31-99
#25-28	0721/3-24-99	0900/3-25	0903/3-25-99	0923/3-25-99	1600/3-27-99	250/3-31-99
#41-44	0721/3-24-99	0900/3-25	0903/3-25-99	0923/3-25-99	1600/3-27-99	250/3-31-99

BALLISTICS TEST AFTER ENVIRONMENTAL TESTING					
1st ARTICLE TEST					
Grenade No.	Trajectory Distance (m)	Remarks	Grenade No.	Trajectory Distance (m)	Remarks
1	20/20/20	(CLC)	25	15/16/16	(CLC) 15 Sec Fame
2	14/15/15	(CLC)	26	0/18/19	(CLC) 9 Sec Flame
3	1/11/11	(CLC)	27	18/19/20	(CLC)
4	1/13/13	(CLC)	28	17/18/18	(CLC) 4 Sec Flame
9	21/22/22	(CLC) 7 Sec Flame	41	20/20/20	(CLC)
10	12/23/24	(CLC) 10 Sec Flame	42	17/17/18	(CLC) 10 Sec Flame
11	10/11/11	(CLC)	43	13/13/13	(CLC)6 Sec Flame(2Cans)
12	17/18/19	(CLC) 6 Sec Flame	44	18/18/18	(CLC)

(CLC) Cold Loose Cargo

Note: It is suspected the grass had something to do with the flaming problem, Some of the canisters would flame out one end and not the other.

Appendix C

Cold Temperature Test with Obturating Disk

<table>
<tr><td colspan="4">M90 LVOSS
2-Aug-99</td></tr>
<tr><td colspan="4">.90 Gr Black Powder, Class 4, LOT # 99F78-69-1
w/obturating disk, 5/8" ID , 2.5" OD, .049 thick
PEL rework w/new obturating disks</td></tr>
<tr><td colspan="4">-50°F Start 7/29/99 @ 1300, Stop 7/30/99 @ 1300
Loose Cargo, Start 7/30/99 @ 1300, Stop 7/30/99 @ 1320
-50°F Start 7/30/99 @ 1320, Stop 8/2/99 @ 0800</td></tr>
<tr><td>No.</td><td>Distance</td><td>No.</td><td>Distance</td></tr>
<tr><td>1</td><td>26/26/26</td><td>23</td><td>22/23/23</td></tr>
<tr><td>2</td><td>23/23/23</td><td>24</td><td>20/21/21</td></tr>
<tr><td>3</td><td>27/27/27</td><td>25</td><td>28/29/29</td></tr>
<tr><td>4</td><td>26/27/27</td><td>26</td><td>25/25/25</td></tr>
<tr><td>5</td><td>24/24/24</td><td>27</td><td>24/24/24</td></tr>
<tr><td>6</td><td>22/23/23</td><td>28</td><td>23/24/24</td></tr>
<tr><td>7</td><td>22/23/23</td><td>29</td><td>23/24/24</td></tr>
<tr><td>8</td><td>21/21/21</td><td>30</td><td>26/26/26</td></tr>
<tr><td>9</td><td>28/28/28</td><td>31</td><td>21/21/21</td></tr>
<tr><td>10</td><td>21/21/21</td><td>32</td><td>22/23/23</td></tr>
<tr><td>11</td><td>25/26/26</td><td>33</td><td>25/26/26</td></tr>
<tr><td>12</td><td>24/25/25</td><td>34</td><td>31/31/31</td></tr>
<tr><td>13</td><td>26/26/26</td><td>35</td><td>24/24/24</td></tr>
<tr><td>14</td><td>21/21/21</td><td>36</td><td>26/27/27</td></tr>
<tr><td>15</td><td>20/21/21</td><td>37</td><td>29/30/30</td></tr>
<tr><td>16</td><td>21/21/21</td><td>38</td><td>25/25/25</td></tr>
<tr><td>17</td><td>21/21/21</td><td>39</td><td>23/24/24</td></tr>
<tr><td>18</td><td>23/24/24</td><td>40</td><td>28/29/29</td></tr>
<tr><td>19</td><td>27/27/27</td><td>41</td><td>26/27/27</td></tr>
<tr><td>20</td><td>25/25/25</td><td>42</td><td>21/21/21</td></tr>
<tr><td>21</td><td>27/27/27</td><td>43</td><td>24/25/25</td></tr>
<tr><td>22</td><td>28/28/28</td><td>44</td><td>25/26/26</td></tr>
</table>