Inert Gas Extinguishing System Two Minute Discharge Study

Gene Hill, P.E.
Brad Stilwell

ABSTRACT

Fire testing per UL 2127 and FM 5600 was done with an inert gas extinguishing system utilizing IG-100, IG-55, and IG-01 agents with the exception that the discharge time was extended from one minute to two minutes to study the effects of an extended discharge time.

INTRODUCTION

NFPA 2001, the governing document for clean agent fire extinguishing systems was approved for a change to increase the discharge time of inert gas systems from one minute to two minutes due to industry pressure both from the manufacturers and customers. Underwriter Laboratories (UL) 2127 and Factory Mutual (FM) 5600 approval standards are based on the one minute discharge originally found in the NFPA document, but now these documents stand to be challenged for the same reasons that the NFPA document was changed. Three inert gasses were tested at the minimum extinguishing concentration per UL 2127 and FM 5600 fire tests: IG-100, IG-55, and IG-01. IG-100 was tested first for both class A and class B in all categories. Based on the results from IG-100 the two other agents were tested with class A polymeric materials only as this was seen to be the most challenging of the UL/FM specified fire tests.

EXPERIMENTAL

The inert gas extinguishing system used for these tests was a Fike ProInert system which regulates discharge pressure to 42 barg. The enclosure measured 15.08 ft. wide by 15.08 ft. long by 16.00 ft. high which required three containers with 572.3 standard cubic feet of agent each. The discharge pipe network consisted of a manifold assembled from 1 inch pipe connected to the main discharge network consisting of a 138 inch vertical run of pipe, a horizontal run of 102 inches and a final vertical run of 18 inches down to the nozzle. All network discharge pipe was 1 inch schedule 40. Three elbows were used in the network. The nozzle used was 1 inch in size with an orifice of .700 inches. The orifice plate chosen for the nozzle was selected to achieve an average nozzle pressure at or below 90% of that which the system was listed which was 104 psi for the equipment used. To limit the gas flow through the network a second orifice plate was added after the manifold at the entrance to the pipe distribution network. The size of the orifice was used to control the rate at which agent flooded the enclosure. The agent minimum design concentration for heptane was obtained from NFPA 2001 for each agent (Harrington et al. 52). Oxygen concentration in the test cell was monitored using a NOVA 320S-3 oxygen meter. The probe for the meter was placed 24 inches over from the corner of the room, elevated 36 inches, and offset from the wall 3 inches. The discharge was tuned by trial and error to achieve the desired agent concentration in the enclosure in 2 minutes. A pneumatically operated ball valve was added to the pipe network just after the orifice plate and was controlled by a pressure switch and timer to close the ball valve at the two minute mark to hold the agent concentration at the desired level. Once the desired

parameters were achieved live fire testing commenced. All tests were run in accordance with UL 2127 and FM 5600 with the exception that the discharge time was extended by one minute. The time in which weight measurement of polymeric material was initiated was delayed by 1 minute from 4:40 to 5:40. You will notice in the chart the heptane pre-burn times were longer than specified in the UL standard as a pre-burn time of exactly 90 seconds is difficult to achieve. The heptane burn time was allowed to be slightly longer than allowed to ensure the most severe conditions possible were encountered. Weight of the polymeric samples was monitored using an Ohaus I20w digital scale with a resolution of 2 grams calibrated to ISO 17025.

IG-100 TESTS

IG-100 was chosen as the agent to begin testing for the simplicity, cost, and speed of the filling process. The minimum extinguishment concentration (MEC) listed in NFPA 2001 for heptane is 31% (Harrington et al. 52). This MEC for heptane was used as the baseline for both Class A and B tests as it provided a good starting point reference. Adjustments to concentration could be made depending upon results. The discharge network was tuned for a 120 second discharge to achieve and hold a 14.4% oxygen concentration. The average nozzle pressure measured was 77 psig, well below the limit of 104 psi. A pan test was run first with the result of extinguishment at 2:24 as measured from the start of the pre-burn; 6 seconds before the end of discharge. Since this test was easily passed if looking at extinguishment time from the end of discharge no additional trials were run and testing proceeded to nozzle distribution verification for the maximum allowable height. The extinguishing system parameters were exactly as before. The last can was extinguished at 1:55 from the start of the 30 second pre-burn (35 seconds before end of discharge, or EOD). It is interesting to note that this test passed per current requirements with 5 seconds to spare. The agent mixing in a room with a two minute discharge appears to be superior to that of a one minute discharge. A possible reason for this may be slower moving gas which prevents stratification and pockets from forming as may be experienced with very strong gas currents during a one minute discharge. Testing then moved onto class A tests starting with a wood crib extinguishment. All test parameters remained as they did with class B tests. The moisture content of the wood crib was measured to be approximately 9.8%. The heptane pre-burn lasted longer than intended at 5:50, but this only created a more difficult test. The crib was extinguished 4 seconds before end of discharge, far in advance of the allowed 600 seconds after end of discharge per current requirements. The crib was removed after the soak period and examined for embers. None were observed. Next polymeric materials were tested with the same parameters. All materials used for the polymeric portion of class A testing were checked by an independent lab to ensure that the material conformed to the requirements of the UL standard (UL 2127 30, FM 5600 19). The heptane pre-burn time was typically 10 to 20 seconds longer than the required time, but again this was seen as a challenging worst case scenario as the plastic will be burning more energetically. ABS was tested first with an extinguishment time of 6:10 (40 s after EOD). The challenge for this test was the

weight loss requirement in which the total weight loss from a period running from 10 seconds to 600 seconds after end of discharge could not exceed 15 grams. The first ABS test lost 10 g while the next two trials lost 12 g each. Although these trials do pass, it is rather close to the limit indicating the agent concentration is at the minimum safe limit. Again, we are examining weight loss from the point 10 seconds after end of discharge which is 5:40 for two minutes rather than 4:40 which would be the mark for a conventional one minute discharge test. Extinguishment times for the last two ABS tests were very similar to the first at 5:50 and 5:58 (20 and 28 s after EOD). Three PMMA trials followed with each losing 10 grams. Extinguishment times for this material are noticeably longer ranging from 7:58 to 8:46 (148 s to 196 s after EOD). One polypropylene trial was completed with an extinguishment time of 5:03; well before the discharge ended. The sample gained weight during the test most likely due to the dripping and shrinking experienced with this plastic. Based on the results no more trials of polypropylene were conducted.

IG-55

The next agent tested was IG-55. Owing to the ease in which class B fires, wood crib, and polypropylene were extinguished only ABS and PMMA tests were conducted for the remainder of the research. The MEC value for heptane given in NFPA 2001 is 35% (Harrington et al. 52), but during the trial and error process of tuning the discharge network a concentration of 34% was achieved and it was decided to proceed even though it was under the specified value. Even with a slightly lower concentration this agent proved to be effective with weight losses of 6 and 8 grams for ABS and 10 grams each for PMMA. Although weight losses were slightly lower for ABS when extinguished with IG-55 than with IG-100, extinguishment times were very similar at 5:46 and 5:52 (16 and 22 s after EOD). Differences in Heptane pre-burn time were negligible eliminating that variable as cause of variation. Extinguishment times for PMMA were nearly identical to IG-100 at 8:27 and 8:51 (177 and 201 s after EOD). Although ABS weight loss numbers were rather modest no reduction in agent concentration was attempted after this series of tests as it was judged that a 5 gram safety factor for PMMA was suitable. Just as with IG-100 weight losses were consistent between all tests.

IG-01

The final agent tested was IG-01. Owing to the fact that IG-55 worked well with a 10% addition of agent the concentration was again increased only 10% to 37% despite a MEC for heptane of 42% (Harrington et al. 52). Weight loss values for PMMA tests were 14 and 12 grams and for ABS were 8 grams each. The ABS numbers were very comparable to what we experienced with both previously tested agents. The weight losses for PMMA were slightly higher than with previous tests most likely due to the longer extinguishment times noted. Extinguishment times were very similar for ABS in comparison to the other agents, but PMMA exhibited somewhat longer times at 10:44

and 9:35 (314 and 245 s after EOD). The one minute inconsistency in those two times translated into a minimal weight loss difference of 2 grams.

DISCUSSION

If one looks at the results of these tests the reader will find that some pass per current requirements and some do not even though the discharge time has been extended by a full minute. Those that do not will conceivably pass if the wording in the UL standard is slightly altered to allow a two minute discharge while still taking weight loss values from the end of discharge. In the course of this research the questions of how the 15 gram requirement came to be and the relevancy of that number are raised. If looking at the weight loss numbers in the chart presented in Appendix A as though these were conventional one minute discharge tests the reader can see that those numbers are approximately double the requirement which sounds like a very large increase. If examining these numbers against the total initial weight we can see that this is in fact a very small number in comparison at close to 1% of total initial weight for the worst cases. If using the limit established in the UL and FM standards a weight loss of ½ % is the current allowable limit (UL 2127 31, FM 5600 17). Although extinguishment times are typically well after discharge has ended the flame has been reduced dramatically by the discharge end. As soon as agent begins to reduce the oxygen concentration in the room the fire begins to weaken. Even with a two minute discharge the majority of agent has entered the enclosure in the first minute and significantly weakened the flame, but it is important to note that the flame does not weaken as fast which results in the higher weight loss results. On a polymeric material test by the end of the two minute discharge the fire has transitioned from a flame engulfing the entire sheet to a flame at the top of the sheet only, burning much like a candle. To examine just how much a fire is reduced during the typical time that an extinguishment occurs one trial was run with PMMA with no extinguishment. At the time in which agent would have been released the samples had lost 36 grams. At the end of what would have been a one minute discharge the samples had lost 92 grams. It was at this point weight loss began to rapidly increase with a total of 184 grams lost at the end of a two minute discharge. The test was halted at 7:50 with a total of 736 grams lost. We can see from this test that any agent introduced to the system begins to control the fire. When examining one minute versus two minute discharges it is easy to see that increased weight losses from the extended discharge are more severe than the original one minute. The opposite seems to be true when looking at nozzle distribution verification tests. The mixing was so thorough that all cans were extinguished 35 seconds before end of discharge. The standards requirement is 30 seconds after end of discharge (UL 2127 32, FM 5600 22). If looking at the timeline of this test from the start of pre-burn the cans must be extinguished by the two minute mark for a standard one minute discharge. The two minute discharge mixes agent in the enclosure so effectively that the extinguishment time for the test conducted was 1:55

which meets the requirements for even a one minute discharge. It seems that the slower discharging agent more effectively mixes in the room as compared to a one minute discharge. The one minute discharge appears to be the worst case scenario of the two. It is for this reason that we recommend that the standards requirements retain the more difficult one minute discharge.

CONCLUSION

From the testing conducted on the three agents we have seen that a minimal change occurs when extending the discharge time from one to two minutes for inert gas extinguishing systems. Of those tests that do not meet the current requirements of UL 2127 and FM 5600 a ½ % increase in weight loss occurs; small enough to be considered negligible. If the standards are altered to allow a two minute discharge and measure weight loss from end of discharge the current weight loss requirements can be retained. The ½ % increase in weight loss of polymeric materials during a fire does not constitute a significant risk to life or property. Nozzle distribution tests should remain as currently addressed in both standards using a one minute discharge as this method appears to be more challenging and we feel the more difficult test should be used. We believe that it is in the best interest of manufacturers and users to support a change to both UL 2127 and FM 5600 to allow a two minute discharge for inert gas extinguishing systems so that the industry may responsibly evolve.

References

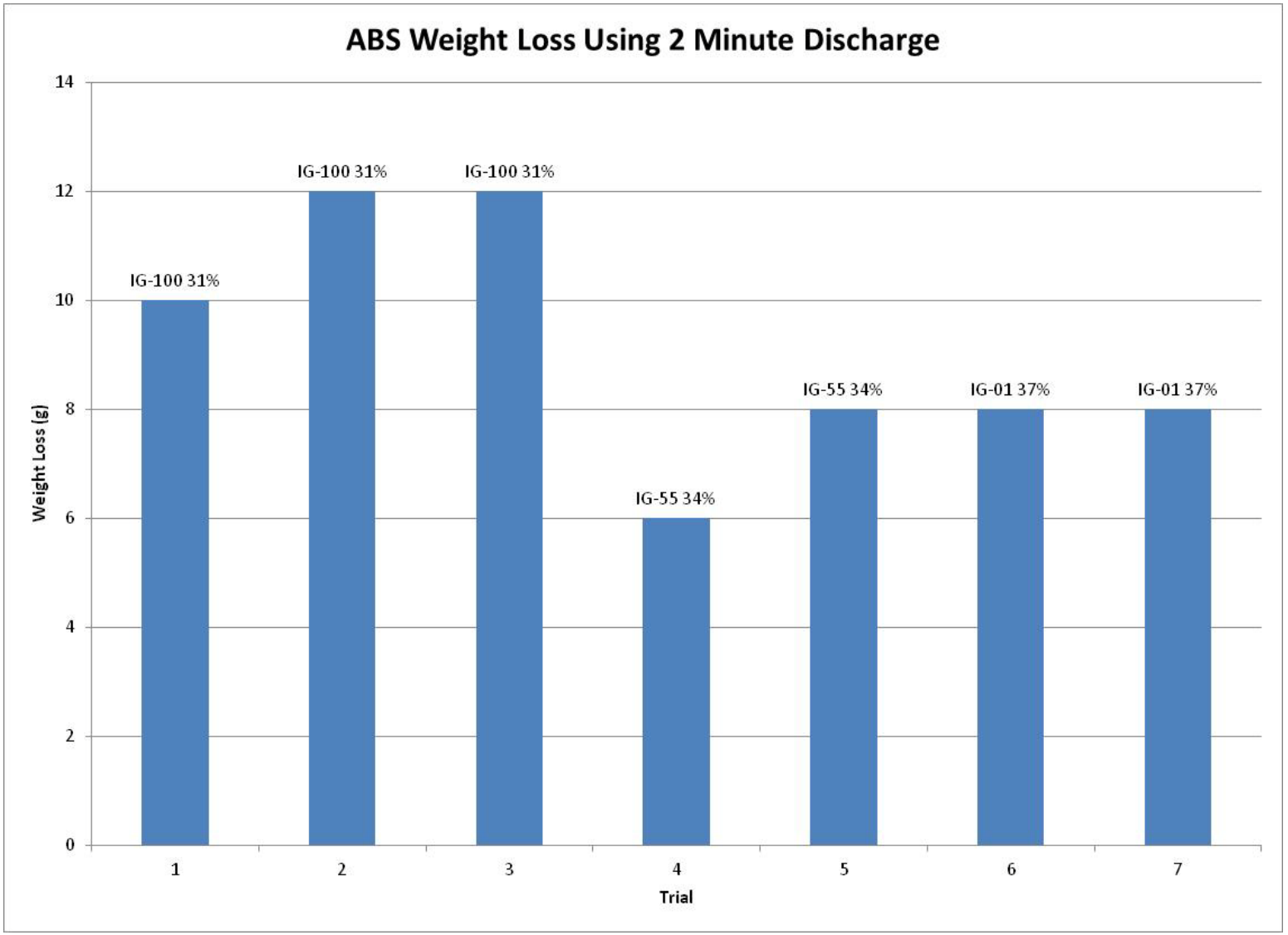
FM 5600 *Approval Standard for Clean Agent Extinguishing Systems*, 2009: 17-19

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2012 Edition: 52

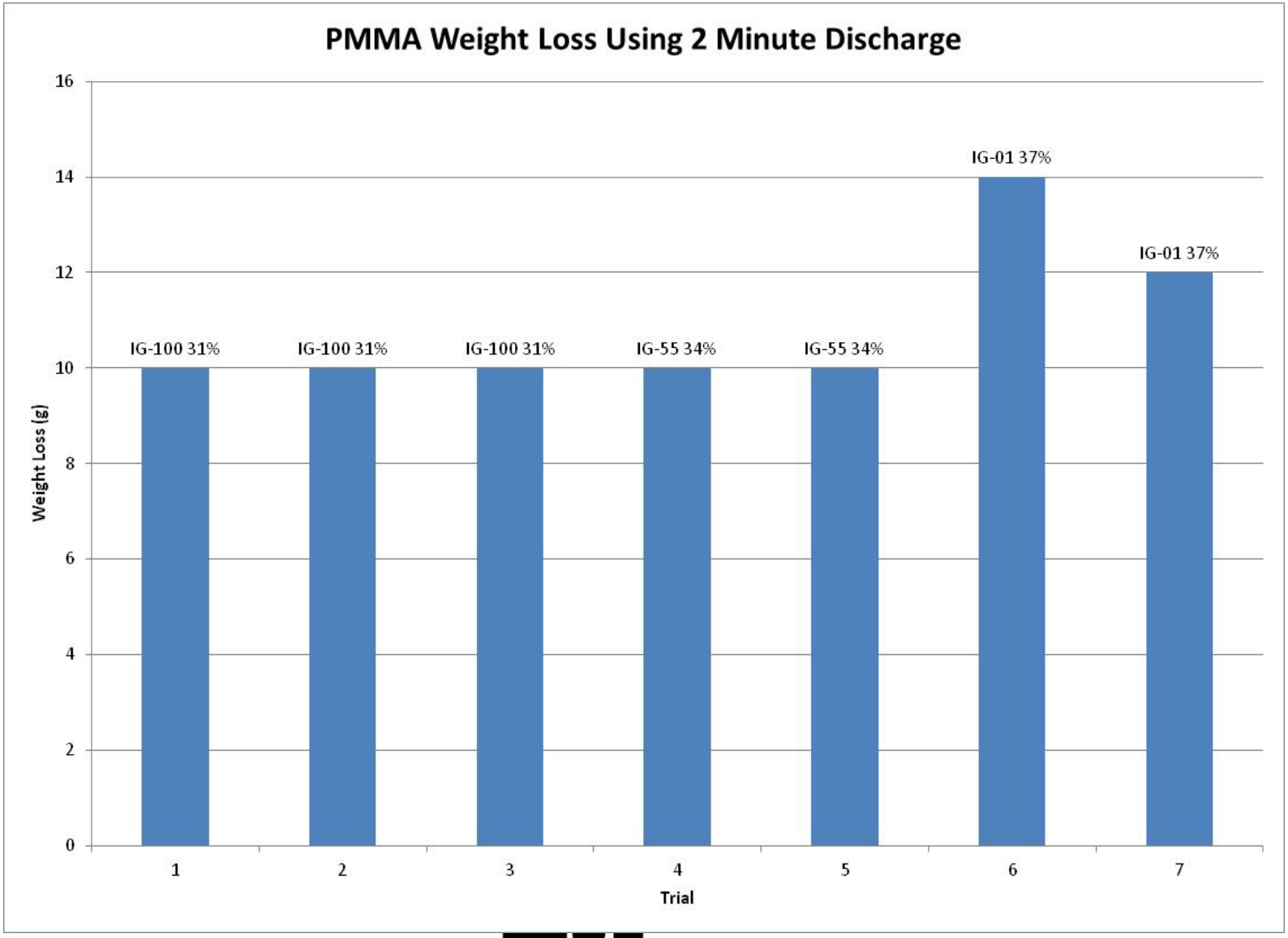
UL 2127, *Inert Gas Clean Agent Extinguishing System Units*, 1999: 30-32

Appendix A

Test	Agent	Agent Concentration %	Weight Loss (g) Using End of 2 Min Discharge	Weight Loss (g) Using End of 1 Min Discharge	Weight Loss (g) from Beginning of Discharge	Total Weight Loss (g)	Extinguishment Time in Minutes from Ignition	Heptane Pre-burn Time in Minutes
Pan	IG-100	31					2:24	:30
Can	IG-100	31					1:55	:30
Wood Crib	IG-100	31					7:56	5:50
ABS	IG-100	31	10	28			6:10	
ABS	IG-100	31	12		96	130	5:50	1:42
ABS	IG-100	31	12	24	104	140	5:58	2:00
PMMA	IG-100	31	10	28				1:00
PMMA	IG-100	31	10	34	86	124	8:46	1:36
PMMA	IG-100	31	10	32	84	124	7:58	1:31
PMMA	n/a	n/a	184	92	692	736	7:50	
Polypropylene	IG-100	31	+170				5:03	1:40
ABS	IG-55	34	6	16	88	130	5:46	1:56
ABS	IG-55	34	8	18	96	146	5:52	1:41
PMMA	IG-55	34	10	34	92	138	8:27	1:51
PMMA	IG-55	34	10	36	90	140	8:51	1:41
ABS	IG-01	37	8	16	80	124	6:11	1:49
ABS	IG-01	37	8	8	66	104	5:41	1:42
PMMA	IG-01	37	14	38	88	136	10:44	1:46
PMMA	IG-01	37	12	34	88	138	9:35	1:40


ABS Weight Loss Using 2 Minute Discharge
Weight Loss (g)
0
2
4
6
8
10
12
14
IG-100 31%
IG-100 31%
IG-100 31%
IG-55 34%
IG-55 34%
IG-01 37%
IG-01 37%
1
2
3
4
5
6
7
Trial

Fike®


PMMA Weight Loss Using 2 Minute Discharge
Weight Loss (g)
16
14
12
10
8
6
4
2
0
IG-100 31%
IG-100 31%
IG-100 31%
IG-55 34%
IG-55 34%
IG-01 37%
IG-01 37%
1
2
3
4
5
6
7
Trial