COMPREHENSIVE PIT TAG EVALUATION PROCEDURE

Outline of tests that shall be conducted to determine if candidate tags can be acceptably detected by the PIT-Tag systems installed throughout the Columbia River Basin

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And

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Introduction

The fisheries community in the Columbia River Basin through research funded primarily by Bonneville Power Administration (BPA) and the US Army Corps of Engineers (Corps) tags around 2 million salmonids each year with FDX-B PIT tags. Most of these fish are tagged with the standard size PIT tags. Currently there are two standard PIT tags. One is 12.34 mm in length by 2.04 mm in diameter, the other is 9.05 mm in length by 2.04 mm in diameter. BPA contracts NOAA (National Oceanic and Atmospheric Administration) Fisheries and PSMFC (Pacific States Marine Fisheries Commission) to evaluate the potential impact of adopting alternative technologies (such as new tag models) before the technology is adopted or installed. This is done because once integrated, these new technologies can have a significant impact on how well the installed interrogation systems detect tagged juvenile and adult salmonids.

NOAA Fisheries and PSMFC work together to evaluate the potential impact of adopting alternative technologies because the agencies have different responsibilities. PSMFC's responsibility is related to operations and maintenance and NOAA Fisheries' responsibility is to ensure that a technology is appropriate for fisheries applications and that the new technologies perform as advertised. This partnership ensures that a technology is ready to move from research and development into operations before it is adopted or installed.

Over the years, BPA has periodically requested that PSMFC and NOAA Fisheries evaluate different models of FDX-B PIT standard tags to determine if they will perform acceptably in the network of interrogation systems installed throughout the Columbia River Basin (check out the PTAGIS Website at www.ptagis.org/ for a description of the sites and their antennas).

One part of evaluating the proposals will be a series of laboratory and field tests that will be conducted to determine if candidate tags could be acceptably detected by the network of PIT-tag systems. This document describes the steps and tests that will be conducted.

NOAA Fisheries published a document in 2005 that described a series of tests that were to be conducted for evaluating new PIT tags (Downing, 2005). PSMFC and NOAA Fisheries still use most of those tests today, but have also been using the large 17' by 17' antenna for the corner-collector detection system at Bonneville Dam. The data collected by the corner-collector detection system provide key data for the survival models used for protecting ESA-listed salmonid stocks. Statisticians from NOAA Fisheries and other agencies have indicated that they need to collect data on a minimum of 60% of the tagged fish going through the corner-collector flume.

In this document, we list the minimum values for passing each test in order for the candidate tag model to continue being tested. During the RFP evaluation process, points will be given for each test based on the results. Furthermore, the performance of any tag model that is evaluated will be compared to the current tag, which is the model TX1400SST-1 (SST) manufactured by Biomark.

All of the steps listed and described below will need to be completed successfully for a tag to be considered for purchase. BPA will be responsible for negotiating contracts with the manufacturer(s). The Corps issues contracts separately from BPA.

Testing will be done in response to the RFP. Manufacturers can request that their tags be evaluated through the PIT Tag Steering Committee or through BPA. If BPA or the PIT Tag Steering Committee requests it, then PSMFC and NOAA Fisheries will also evaluate specialty tags that are outside the standard size range. Often, these evaluations consist of laboratory tests only. There are fewer steps to be completed for specialty tags because the focus of the testing is to inform the fisheries community of their general level of performance and to ensure that the tags do not negatively impact the data collection of fish tagged with the standard size tags. On the last page, we list the tests we recommend running for the specialty tags based on their length.

Steps Involved in the Evaluation Standard Size PIT Tags

There are multiple steps involved in the evaluation of a new standard sized tag model. Each step or test must be passed before the evaluation proceeds to the next step or test.

Step 1) Tag model must pass hit-rate tests with the corner-collector antenna

Step 2) Tag model must satisfy length, diameter, and weight limits

Step 3) Tag model must pass the preliminary reading-efficiency tests

Step 4) Tag model must pass the following laboratory tests

- Test A. Electrical parameter testing performed with Automated PIT Tag Testing System (APTTS)
- Test B. Read range tests under different noise levels
- Test C. Maximum read speed tests under different noise levels
- Test D. Two-same-tag grouping/proximity tests
- Test E. Three-same-tag grouping/proximity tests
- Test F. Three-different-tag grouping/proximity tests
- Test G. Drop test
- Test H. Pressure test

Step 5) Tag model must pass fish test with the corner-collector detection system

With each of the above tests, the appropriate transceiver shall be used for that size antenna. In other words, the FS1001J shall be used for the 12” pipe antenna that represents most antennas found at the bypass facilities for juvenile salmons, the FS2020 for the orifice antenna or 4’ by 4’ antenna, and the B2CC transceiver shall be used in the corner-collector tests.

Before any belt tests can be conducted, the evaluators shall determine the minimum non-interfering distance between the tags of the same model using both shielded and unshielded antennas. They shall then increase the longer of the two distances between tags by a minimum of 15% and use that distance for separating tags in the following tests. This will often determine how many sets of tags can be used in the different tests.

The series of grouping tests shall only be done with the 12” pipe antennas because grouping is a common situation for juvenile salmonids while it has not been observed in the interrogation systems for adult salmonids.

Under the description for each test, we indicate the minimum result that must be reached for the candidate tag to continue testing. Meeting the minimum does not mean that the tag will be recommended for use by the fisheries community; it needs to perform as well as or better than the current tag. If a tag model does not meet that minimum requirement for any test; we will stop testing it and will <u>not</u> recommend the tag for widespread use in the Columbia River Basin.

Step 1 Test (hit-rate tests in the ½-scale corner-collector detection system)

Since the data collected by the corner-collector detection system at Bonneville Dam are key to the survival models used for protecting ESA-listed salmonid stocks, NOAA Fisheries has decided that PIT tags must be detected well in that system to be acceptable. If a tag cannot perform well in the corner-collector detection system, then there is no reason to spend the time determining how well it performs in the other detection systems for juvenile and adult salmonids.

In 2006, BPA contracted Digital Angel Corporation (aka Destron Fearing) and PSMFC to install a PIT-tag detection system that Digital Angel designed to fit into the exit flume for the corner collector at Bonneville Dam (Figure 1). The corner-collector PIT-tag system is unique in many ways: 1) it has the largest (17'x17') RFID full-duplex antenna for fisheries applications, 2) it has only one antenna instead of multiple antennas, and 3) it has a specialized transceiver designed specifically for this application.

Tests will be conducted in the ½-scale model of the BCC antenna in PSMFC's large RF room. For these tests the evaluators shall connect a lab power supply to reduce the amperage accordingly.

For these tests, the B2CC transceiver shall be put into the diagnostic mode, where the number of times a tag is read out of 100 opportunities is reported. The output of this diagnostic mode is called the hit rate. During the testing, the transceiver shall be periodically taken out of the diagnostic mode so that noise measurements can be recorded.

Using an apparatus made of non-ferrous material, tags shall be placed into the field in two positions that are measured from the inside of the antenna housing (Figure 2). They are the center point (4.25', 4.25'; horizontal, vertical measurements) and near one of the corners (1', 1'). The tags shall be centered in the Z-axis of the antenna. The tags shall be attached to the test apparatus using plastic blocks and Velcro.

As a control, SST-1 tags shall be tested each time the test is conducted. Ten PIT tags from each tag type shall be chosen randomly for the test. All the tags shall be tested in the corner location first, and then the apparatus shall be moved to the center location. At each location, each tag shall be tested in both 0° and 45° orientations relative to the Z axis, which is the optimal orientation for the antenna. The tag types shall be alternately tested (i.e., TypeA-1, TypeB-1, TypeA-2…). The order for the 20 tags (or more if two or more tag types are tested simultaneously) shall be kept constant for all four sets of tests. For each of the four tests, 10 hit rates shall be recorded for each tag. An average hit rate shall then be determined for each candidate tag type in each location and each orientation.

Figure 2. Photo of the ½-scale model of the BCC antenna. Note the RF shielded room, aluminum shield and pneumatic shuttle.

If a candidate tag type averages a hit rate of <98% in the corner position for either orientation, then it shall not be tested in the center position.

If for some reason, the hit rates drop unexpectedly, the noise levels for the B2CC transceiver shall be immediately be checked. If noise badly affects the hit rates, then all tags shall be run under the higher noise conditions. Alternatively, the test shall be repeated when conditions improve.

If for some other reason, the hit rates inexplicably decrease (i.e., the noise levels remain the same), then the evaluators shall repeat the tags that have already been completed so that all of the tags are tested under the same conditions. Alternatively, the affected set of tests shall be repeated either later that day or on another day when conditions improve.

- Testing stops here if the average hit rate for the corner location is ≤ 98% for 0°-oriented tags.
- Testing stops here if the average hit rate for the center location is ≤ 98% for 0°-oriented tags or ≤ 90% for 45°-oriented tags.

Step 2 Tests (length, diameter, and weight)

1) Measure the individual length and diameters (in millimeters) of 30 tags to the second decimal point. The tags shall be individually measured using a micrometer that measures accurately to 0.01 mm (e.g., Starrett Model 721) or with the APTTS. Record the individual values and determine the average value and the standard deviation. Tags must pass freely through the bore of a standard 12-gauge veterinary hypodermic needle.

    - Testing shall stop at this point if the candidate tag does not have an average length of ≤ 12.7 mm (or 9.3 mm for the shorter standard tag) and an average diameter of ≤ 2.14 mm.
    - The fisheries community prefers tags with lengths <12.5 mm; therefore during the RFP evaluation, higher scores shall be given to tags with average lengths <12.5 mm.
    - The tag must fit into the bore of a standard 12-gauge or smaller needle or the testing shall stop here.

2) Measure the individual weight (in grams) of 30 tags to the second decimal point. The tags will be individually weighed on an electronic analytical balance that weighs accurately to 0.0001 g (e.g., Mettler AE100). Record the individual values and determine the average value and the standard deviation.

    - Testing shall stop at this point if the candidate tag does not have an average weight of ≤ 0.115 g when measured in air.
        - The fisheries community prefers tags with weights <0.105 g; therefore, during the RFP evaluation, higher scores shall be given to tags at or below this weight.

Step 4 Tests (laboratory tests)

Test A. Electrical parameter testing performed with APTTS

Details on the operation of the Automated PIT Tag Testing System (APTTS – Figure 4) can be found in Brower and Warf (2010). A minimum of 200 PIT tags will be tested. The fixed voltage that shall be used in the amplitude and resonant frequency tests will be determined for the specific tag model. It shall be determined with 10 tags. Then, the entire group of 200 tags shall be tested in one automated batch.

Once the APTTS is set up, results for the following electrical parameters shall be collected:

- Amplitude returned from the PIT tag when it is energized with a 134.2-kHz constant amplitude wave form.
- Resonant frequency, measured to the nearest 25 Hz resolution.
- Turn-on voltage, measured to the nearest 10 mV.
- Bandwidth at -3dB (kHz)
- Q
- Modulation percentage

- Testing shall stop here if
  - 98% of the tags do not have modulation values > 75%
  - 98% of the tags do not have turn-on voltages values ≤ 700 mV
  - 98% of the tags do not have resonant frequency values of 132-136.5 kHz
  - 98% of the tags do not have bandwidth values < 9 kHz

Figure 3. Photo of the APPTS.

Test B. Read ranges under different noise levels

PSMFC is building the Kennewick Automated Read Range Tester (KARRT). The KARRT will move the tags into the ½-scale model of the BCC antenna in PSMFC's large RF room. This will eliminate human error, record the data automatically and speed up the process. "Read ranges under different noise levels" will be tested using one of two tests, KARRT or the manual method used in the BPA RFO in 2011.

KARRT Test:

Randomly choose 30 PIT tags from the group of tags. The same tags shall be used in both parts of Test B. Data shall be collected on the tags in 0° and 45° orientations relative to the Z axis of the antenna. The tags shall only be tested with the tags going into the center of the antennas. The test shall be conducted in the ½-scale model of the BCC antenna in PSMFC's large RF room

The KARRT (Kennewick Automatic Read Range Tester) will be used to move the tags into the field. Each PIT tag to be tested shall be placed on the carriage and moved straight into the center of the field, at ~2"/second until the transceiver registers a read. That distance, the PIT tag from the center of the antenna, shall be recorded. The distance shall be recorded to the nearest ¼". The tag shall then be pushed farther into the field 0.25" at a time, pausing for 3.053 seconds (the minimum time it takes to read a tag 100 times). The next distance measurement shall be recorded when the tag is read 300 times in 9.159 seconds.

The noise for the tests shall be created using a function generator outside of the RF room that is connected to a noise antenna inside the screen room. The noise antenna shall be driven with a 132.2 kHz sine wave. The amplitude shall be varied to provide controlled noise.

If the tag does not reach the 1 or 100% read count, then the read-range distance shall be recorded as N/A.

i. Run these read range tests with the ½-scale model of the BCC antenna with 0 and 10% added noise.

  - Testing shall stop at this point if the median read range for 100% hit rate for the 0°-oriented tags is < XX" with no added noise (XX will be determined from the currently approved BPA tag).

Manual Test:

Randomly choose 30 PIT tags from the group of tags. The same tags shall be used in both parts of Test B. Data shall be collected on the tags in 0° and 45° orientations relative to the Z axis of the antenna. The tags shall only be tested with the belt in the center of the antennas. The test shall be conducted in a RF-screen room.

Like in the Step 1 test, the transceivers shall be set into the diagnostic mode where the number of times a tag is read out of 100 opportunities is reported. The output of the diagnostic mode is known as the hit rate.

Each PIT tag to be tested shall be placed on the belt and moved by hand straight into the center of the field, pausing 4 seconds at each ¼" increment for the transceiver to register a hit rate. The first read range (i.e., the distance of the PIT tag from the center of the antenna) shall be recorded when the display reads a hit. The distance shall be recorded to the nearest ¼". The tag shall then be pushed farther into the field and the next distance measurement shall be recorded when the display reads a hit rate of 100%.

The noise for the tests shall be created using a function generator outside of the RF room that is connected to a noise antenna inside the screen room. The noise antenna shall be driven with a 132.2 kHz sine wave. The amplitude shall be varied to provide controlled noise.

If the tag does not reach the 1 or 100% hit rates, then the read-range distance shall be recorded as equaling zero.

ii. Run these read range tests with the 4' by 4' antenna with 0 and 10% added noise.

- Testing shall stop at this point if the median read range for 10% hit rate for the 0°-oriented tags is < 21" with no added noise.

Test C. Maximum read speed

The evaluators shall conduct this test using the ½-scale model of the BCC antenna in PSMFC's large RF room with the pneumatic shuttle.

The tags will be passed through the antenna at ~80'/second (the actual velocity will be recorded for each repetition). The number of times the tag is read will be recorded for each pass.

Determine the number of reads for each tag type.

- Testing shall stop at this point if the candidate tags cannot be detected at the 50% level compared to the currently approved BPA tag.

Test D. Two-same-tag grouping/proximity tests

This test shall be run with the standard <u>shielded</u> 12” antenna configuration used at sites for juvenile salmon (two coils shall be wrapped 18” apart within a 48” aluminum shield). Standard shield dimensions are a minimum of twice the pipe size. Noise levels shall be kept at a minimum (<250 mV above the baseline voltage; below 100 mV if possible) and the levels during testing shall be recorded.

The evaluators shall determine the effect on reading efficiency for each tag type at a fixed belt speed (13±0.5 ft/sec) with each set of tags separated by different distances. The test shall be conducted with the belt in the center position and with tags in 0° orientation relative to the Z-axis of the antennas.

There shall be a minimum of five replicate tag groups. Within each tag group, set distances shall separate tags (e.g., Tag1-testspace-Tag2) and then each tag group shall be separated from the next group by the non-interfering distance. Reading efficiencies shall be calculated out of a minimum of 2,000 detections. Results shall be recorded for each of the two coils separately and combined.

In this first grouping test, Tag1 and Tag2 shall be the same tag type. Determine reading efficiencies when tags are separated by 6” and 3”. The distances shall be measured by tip of one tag to the tip of the next tag.

- Testing shall stop here if the candidate tags cannot be detected >98% when two tags are separated by 6” in the 12” antenna.

Test E. Three-same-tag grouping/proximity tests

In this series of tests, the tag group will consist of three tags that are all of the same type. In this scenario, the middle tag will not be detected as well because both outside tags will affect it by reducing the time it can be read without another tag being in the field simultaneously. Therefore, the two outside tags will behave similarly and the middle tag will behave uniquely. Therefore, reading efficiencies shall be calculated for these two subgroups separately (i.e., outside tags and middle tag).

These tests shall use the same shielded antenna setup as in Test D. A minimum of three replicate tag groups, each with three tags, shall be used (the number of tag groups that can be tested simultaneously will depend on belt length and the established non-interfering distance). Within each tag group, set distances shall separate tags (e.g., Tag1-testspace-Tag2-testspace-Tag3) and each tag group shall be separated from another by the non-interfering distance. Reading efficiencies shall be calculated out of a minimum of 2,000 detections; it may be more depending on how many 3-tag replicate groups were run. Results shall be recorded for each of the two coils separately and combined.

The belt shall be run at 13±0.5 ft/sec with the tags in the 0° orientation. Determine reading efficiencies when tags are separated by separated by 12” and 8”.

- Testing shall stop here if the candidate tag in the middle position cannot be detected at >99% when the tags within a single tag group are separated by 12” in the 12” antenna.
- Testing shall stop here if the candidate tag in the middle position cannot be detected at all when the tags within a single tag group are separated by 8” in the 12” antenna.

Test F. Three-different-tag grouping/proximity tests

The same test as in Test D shall be run, but in this test the stronger tag model shall be used as the outside tags and the weaker tag model as the middle tag (e.g., SST-New-SST). The stronger tag shall be the tag model with the longer non-interfering distance. Reading efficiencies shall be calculated separately for the different tag types.

- Testing shall stop here if the tag in the middle position cannot be detected at >99% when the tags within a single tag group are separated by 12” in the 12” antenna.
- Testing shall stop here if the tag in the middle position cannot be detected at all when the tags within a single tag group are separated by 8” in the 12” antenna.

Test G. Drop test

To simulate what could happen in the field when fish are being tagged, 10 tags shall be rolled (lightly nudged) from a height of 42” onto a concrete floor. Each tag shall be dropped three times. For verification, tags shall be read before and after dropping with a Destron Fearing FS2001F reader. We shall also record whether the glass breaks on any of the tags. If the glass breaks, photos shall be taken to record how each glass broke.

- Testing shall stop here if more than 2 tags stop reading or if more than 40% (4) of the tags break their glass (this includes cracks).

Test H. Pressure test

The evaluators shall randomly choose 30 PIT tags and confirm that they all read with a transceiver. They shall then put the tags into the pressure chamber with water that is approximately 40-50° F (refrigerated).

For the first test, increase the pressure by 50-100 psi/sec until the chamber reaches 1,000 psi. Hold the pressure for 90 seconds. Then bring the pressure down using a similar rate (50-100 psi/sec). Visually inspect the tags for breakage and confirm that they all read. Record any breakage (take photos) and record the number of tags that do not read. If 10% (three) or more of the tags stop reading or break, stop the testing.

If less than 10% are either broken or do not read, then use the remaining good tags for the next pressure test. Repeat process, but increase the pressure to 2,000 psi. If 10% or more of the remaining tags stop reading or break at 2,000 psi, but this was not true at 1,000, then retest remaining tags at 1,500 psi.

If less than 10% are either broken or do not read at 2,000 psi, then skip the 1,500 psi test and use the remaining good tags for the next pressure test. In this test, take the pressure up to 2,000 psi, hold it for 90 seconds, and back down to 50-100 psi and then back up and down five times (holding it each time for 90 seconds). After these six cycles, examine the tags for breakage (take photos) and test if they read.

- Testing shall stop here if 10% or more of the tags stop reading or break during any of the tests.

Step 5 Fish test in corner-collector detection system

The fish test shall only be conducted if the candidate tag has passed all the other tests in this document with scores that are at least within 10% of the current SST tag and if BPA is considering buying the tag based on their other criteria.

This test will use 1,000 production tags. This test is normally conducted in April when the corner collector flume is first watered up and hatchery fish are available for testing.

NOAA Fisheries did some preliminary fish tests in 2006 to help Digital Angel in setting up their system. They then evaluated the corner-collector detection system in 2007 with fish tests using fish from the three main salmonid populations (yearling and subyearling Chinook salmon, and steelhead). The results were consistent across the different populations; basically, NOAA Fisheries determined that the detection system detected approximately 40% of the fish tagged with the ST PIT tags and 70% of the fish tagged with the SST PIT tags. Given that the SST tag yielded a detection rate above the 60% rate that the statisticians required and satisfied the length, diameter, and weight limits, it became the standard PIT tag used throughout the Columbia River Basin.

For this fish test, the evaluators shall tag 1,000 hatchery yearling Chinook salmon for each tag model being tested and tag 1,000 fish with the current PIT tag (SST). The fish shall be tagged at Bonneville Dam. The fish shall then be held for 24 hours in 44-gallon containers before they are released individually in front of the entrance to the corner collector through a 4" hose (Figure 5). The release location is within the capture velocity area and so the fish have to go down the corner-collector flume. During the release process, the evaluators shall scan each fish to record its tag code before the fish is released. Furthermore, they shall alternate the tag types in case electromagnetic noise levels rise unexpectedly.

Figure 4. The left photo shows the deck where fish are held in tanks and released. The right photo shows the hose leading down to the entrance of the corner-collector flume.

After being released, the fish go immediately down the corner-collector flume, past the PIT-tag antenna, and then directly into the Columbia River. Releasing 1,000 tagged fish in each group will yield detection rates with around 3% precision levels (the exact level depends on the detection rate). Therefore, the evaluators shall get solid estimates of the performance of the candidate PIT tags.

- The candidate tag shall not be acceptable for use in the Columbia River Basin if it does not yield a reading efficiency of 60% in this fish test.

Steps Involved in the Evaluation of Specialty Tags

There are multiple steps involved in the evaluation of a new specialty tag model. Since these tags may be of different lengths, the evaluators shall modify the tests listed above accordingly. Except for the tests in Step 2 below, there would be no pass/fail criteria for these tags; the testing is just to provide information. Although the evaluators might choose to conduct a more robust set of tests to learn more about the tags, these are the minimum set of tests be conducted on any specialty tag model whose use is expected to result in the detection of at least 5,000 tagged animals annually.

Step 1) We will measure the length, diameter, and weight as described in Step 2 above.

Step 2) Tag model must pass the preliminary set of reading-efficiency tests described in Step 3 above.

Step 3) The following tests are run for tags <10 mm in length

Test A. Electronic parameter testing performed with APTTS

Test B. Read ranges (10% hit rate) on the 4’ by 4’ antenna with no noise added

Test C. If the tags cannot be read in the center of the 4’ by 4’ antenna, then the read ranges recorded shall be the distance measured from the side of the antenna (out from the middle of one of the sides). The tags shall still be in the 0 orientation relative to the Z axis.

OR

Step 3) The following tests are run for tags >15 mm in length

Test A. Electronic parameter testing performed with APTTS

Test B. Read ranges (10% hit rate) on the 4’ by 4’ antenna with no noise added

For all of these tests, the appropriate transceiver will be used for that size antenna. In other words, the FS1001J will be used for the 12” pipe and the FS1001A for the orifice or 4’ by 4’ antenna

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Revision History

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