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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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 (USACE), tags around 2 million salmonids each year with FDX-B PIT (passive integrated transponder) tags. Most of these fish are tagged with one of two standard size 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 or transceivers, before the technology is adopted or installed. This testing is critical because once integrated, these new technologies can have a significant impact on how well the current interrogation systems detect tagged juvenile and adult salmonids for timing of migration and survival estimation.

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 of detection sites for real-time data provided to the Basin, and NOAA Fisheries' responsibility is to ensure that a technology is appropriate for fisheries applications and that the new technologies perform as advertised through evaluation. This partnership ensures that a tag or 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 standard FDX-B PIT tags to determine if they will perform acceptably in the network of interrogation systems installed throughout the Columbia River Basin (see the PTAGIS Website at www.ptagis.org for a description of the sites and associated detection systems).

The evaluation process consists of a series of laboratory tests that are conducted to determine if candidate tags could be acceptably detected by the network of PIT-tag systems. 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 have modified those tests by utilizing a large 17' by 17' antenna representative of the corner-collector detection system in use at Bonneville Dam (½-scale BCC model antenna). The data collected by the corner-collector detection system provides key data for the survival models used for evaluating ESA-listed salmonid stocks. Given its importance for detection, we have determined that the ½-scale model provides the most realistic evaluation tool for tag testing purposes.

In this document, we list the minimum values determined for passing each test for the candidate tag model to continue being tested. During the 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 as of this writing is the model APT12 manufactured by Biomark.

All 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 selected manufacturer(s). The USACE issues contracts separately from BPA.

Testing will be conducted in response to a request from BPA to evaluate available production tags. 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. 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 test must be passed before the evaluation proceeds to the next step.

Step 1) Tag model must satisfy determined length, diameter, and weight limits

Step 2) Tag model must pass hit-rate tests with the ½ scale corner-collector antenna

Step 3) 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. Drop test
- Test E. Pressure test

With the above tests in step 2, the appropriate transceiver shall be used for that size antenna. In other words, the B2CC transceiver shall be used in the corner-collector tests. Prior to the BCC testing, the FS1001J was used for the 12" pipe antenna that represents most antennas found at the existing bypass facilities for juvenile salmons, and the FS2020 for the orifice antenna or 4' by 4' antenna.

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 Tests (length, diameter, and weight)

1) Measure the individual length and diameters (in millimeters) of 30 randomly selected tags to the second decimal point. The tags shall be individually measured using a micrometer that measures accurately to 0.001 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 randomly selected tags to the third 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 2 Test (hit-rate tests in the ½-scale corner collector detection system)

In 2006, BPA contracted Digital Angel Corporation (aka Destron Fearing), PSMFC, and NOAA 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 pass-through antenna for fisheries applications, 2) it has only one antenna instead of multiple antennas, and 3) it has a specialized transceiver (FS3001) designed specifically for this application.


Figure 1. PIT tag antenna being lowered into place at the corner collector flume at Bonneville Dam, 2006.

Since the data collected by the corner collector detection system at Bonneville Dam are key to the survival models used for evaluating 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.

Tag tests are conducted in the ½-scale model of the BCC antenna in PSMFC's large RF room in order to replicate detection conditions at BCC. For these tests, the evaluators shall connect a lab power supply to reduce the amperage accordingly. In addition, the B2CC Ogee transceiver shall be put into 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, the currently approved BPA tag 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 0° 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 for passing the PIT tag through the antenna automatically.

If a candidate tag type averages a hit rate of 98% in the corner position for either orientation, then it shall be tested in the center position.

- *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 3 Tests (laboratory tests)

Test A. Electrical parameter testing performed with APTTS

The Automated PIT Tag Testing System (APTTS – Figure 4) energizes the tag with a range of frequencies from 94.2 kHz to 174.2 kHz (40 kHz above and below the nominal 134.2 kHz of the PIT tag).

The signal returned from the PIT tag is then analyzed for amplitude to determine the frequency with the highest amplitude. The antenna system was designed to reduce bias from reading the tag's microchip end before the antenna end, enabling consistent automated testing. 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 each 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. Amplitude is a simple measurement of raw signal returned from the tag while it is activated. *Higher numbers are better*.
- Resonant frequency, measured to the nearest 25 Hz resolution. Resonant frequency should ideally be the ISO standard 134.2kHz. Testing methodology affects the measurement/result, so *these data are more relevant for showing consistency from tag to tag within the test group.*
- Turn-on voltage, measured to the nearest 10 mV. Turn-On voltage is an indication of how much energy is needed to activate a tag. *Lower numbers are better.*
- Bandwidth at -3dB (kHz). Each model of PIT tag has a characteristic bandwidth. A PIT tag's bandwidth is the range of frequencies, from above to below the resonant frequency, where the tag is most effective. *Typically, a narrow BW is better.*
- Q. "Q" is another common method for characterizing frequency response. The Q is derived from the bandwidth, determined by this formula: Freq@Peak / (Freq@+3dB – Freq@-3dB) *Typically, a higher Q is better (if the transceiver is tuned close to 134.2kHz).*
- Modulation percentage. Modulation percentage is a measure of how strong the tag sends its data to the transceiver. *Higher percentages are better.*

Testing shall stop here if:

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

Figure 3. Photo of the Automated PIT Tag Testing System (APTTS).

Test B. Read ranges under different noise levels

PSMFC will use the Kennewick Automated Read Range Tester (KARRT) for this test. The KARRT will automatically 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 provide efficiency to the process. "Read ranges under different noise levels" will be tested using one of two tests, KARRT or the manual method which was used in the BPA RFO evaluation 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 the 0° orientation 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 automatically moves individual tags into the field in small increments. Each PIT tag to be tested shall be placed on the carriage and moved straight into the center of the field, at approximately 2"/second until the transceiver registers a read. That specific distance, the PIT tag from the center of the antenna, 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 RF 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.

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).*

<u>Manual Test (if BCC model is not available)</u>

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 the 0° orientation relative to the Z axis of the antenna. The tags shall only be tested with a belt in the center of the antennas. The test shall be conducted in a RF-screen room.

Similar to 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 RF 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.

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 approximately 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. 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 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 breaks.

- *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 E. 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 4.5-10° C.

For the test, increase the pressure by 50-100 psi/sec until the chamber reaches 2,000 psi. Hold the pressure for 90 seconds. Then bring the pressure down using a similar rate (50-100 psi/sec). Repeat this back up and down five times (holding it each time for 90 seconds). After these six cycles, examine the tags for breakage (take photos of any breakage) 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.*

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 to 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) 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 these tests, the appropriate transceiver will be used for that size antenna.

References

Sandra L. Downing, Alan Brower and Don Warf. Process for Evaluating Candidate Pit Tags In 2011. 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.

Downing, S. 2005. Procedures for evaluating candidate PIT tags: Description of tests that shall be conducted to determine if the candidate tags can be successfully adapted to the PIT tag systems installed throughout the Columbia River Basin. Technical Report prepared for Bonneville Power Administration and PIT Tag Steering Committee.

Revision History

Rev 0 – October 2016 - Initial release – Axel, Brooks, Brower, Warf

Rev 1 – March 2017 – Redefined "standard tags" to include 9mm types – Brower

Rev 2 – April 2023 – Clarify KAART testing, remove live fish test, clarify and streamline testing - Brower

Rev 3 – June 2026 – Clarify testing procedures and remove belt testing from protocols – Axel