INDEX TEST BOX (ITB)

A REPORT ON THE RESEARCH, DEVELOPMENT AND "PROOF OF CONCEPT" DEMONSTRATION OF A TYPE 1 GENERATION UNIT OPTIMIZING DEVICE

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EXECUTIVE SUMMARY

An Index Test Box (ITB) is a Type 1 generating unit optimizing device. It is intended to conduct index or relative efficiency tests on hydraulic turbines, particularly Kaplan turbines. It is designed to do this in an automatic, unattended, manner and the output is a data stream used to separately prepare graphs of the optimum cam(s) and efficiency profile(s). An early version of the ITB was developed twenty years ago and successfully tested; however, it never entered the commercial market. This present effort was to develop a GDACS (Generic Data Acquisition and Control System) compatible version of this ITB using new, modern computer capabilities.

A sole source contract was negotiated with the inventor of the original ITB. This contract, with Actuation Test Equipment Company (ATECo), recognized that certain aspects of ATECo's software had been pre-developed and therefore the government had only "limited rights" to such code. The contract eventually had three modifications issued, the first was never executed and the other two were both for time and cost extensions as well as changes in work scope. Unit #5 at McNary was selected as the first test unit. However, when an anomaly was detected with the Winter-Kennedy piezometers, this was shifted to unit #9. Ultimately, performance data was also recorded at Ice Harbor unit #3.

One additional part of ATECo's effort was in achieving an interface with the GDACS. ATECo was directed by the contract to use the data signals contained in the GDACS. However, the GMT (GDACS Maintenance Team) prohibits the interconnection of any other software system without having a complete source code. ATECo refused to provide the source code of the pre-developed portion of the software code to which the Government did not have rights. After several delays and false starts, ATECo eventually bought the information on how to effect the interconnection from another contractor, Automatic Control Systems, Incorporated (ACSI).

Several field trips were made to McNary in order to successfully record the performance data necessary to demonstrate the "proof of concept." However, a software program to accurately reduce the data on a production basis still needs to be developed. The difficulty of this is exacerbated by the dynamic characteristics of the present governors that are unable to hold the measured parameters sufficiently constant. Also, an automatic flushing system for the Winter-Kennedy piezometers to be used in conjunction with the ITB still needs to be developed.

The Contractor has filed formal complaints with the Inspector's General of the US Department of Energy and US Department of Defense. These are still pending. He has also filed three requests under FOIA (Freedom of Information Act). The first was denied, the second was placed in a hold status pending resolution of an investigation, and the third is awaiting response.

Future plans include purchasing two more ITB's from ATECo. One will be permanently installed in a GDACS powerhouse and the other will be a non-GDACS version. It is planned to use the lessons learned in this contract to prepare a solicitation for the development of a prototype ITB system for further evaluation and then even a production version of the ITB for installation in all the Corps' powerhouses in the Pacific Northwest.

TABLE OF CONTENTS

List of Appendices

List of Abbreviations

BPA – Bonneville Power Administration, US Department of Energy
COTR – Contracting Officer's Technical Representative
EPROM – Erasable Programmable Read Only Memory
EEPROM – Electronically Erasable Programmable Read Only Memory
FOIA – Freedom of Information Act
FY – Fiscal Year
GDACS – Generic Data Acquisition and Control System
GMT – GDACS Maintenance Team
HDC – Hydroelectric Design Center, US Army Corps of Engineers
IG – Inspector General
ITB – Index Test Box
MW – megawatt
NWP – Northwestern Division, Portland District, US Army Corps of Engineers
NWPR – Northwestern Division, Portland District, Regional
OEM – Original Equipment Manufacturer
OLE – Object Linking Code
OPC – Process Control Communication
PGE – Portland General Electric
PLC – Programmable Logic Controller
R, D & D – Research, Development and Demonstration
R & D – Research and Development
SDK – Software Designer's Kit
T1 – Type 1 optimization
USDOD – US Department of Defense
USDOE – US Department of Energy
3-D – Three Dimensional cam

INDEX TEST BOX
A REPORT ON PROCUREMENT AND DEMONSTRATION

ORIGINAL INDEX TEST BOX

In the 1980's the Bonneville Power Administration (BPA) contracted with Portland General Electric (PGE) to purchase, install and test an optimizing device from Woodward Governor Company. This device was known as an Index Test Box (ITB) and was designed to optimize the performance of hydraulic turbines. In particular, it was designed to conduct automatic, unattended, index tests on Kaplan turbines to determine the optimum blade to gate or cam curve to input into the governor control system. The hardware interface of this first prototype device was capable of working only with Woodward's new electronic 3-D cam and electronic "load feedback" governors.

This first commercial version of the ITB was purchased from Woodward for $68,000 and installed and evaluated at PGE's Portland Hydro Plant #2 in the Bull Run watershed on Mt Hood. This project did not use fish screens in the intake. The evaluation was done by first installing and then turning the ITB on for one week. After removing it, a conventional, manual, index test was conducted. A comparison of the results from the two tests showed perfect agreement, meaning the ITB had correctly determined the optimum cam for that particular Kaplan at the designated test head. A complete report on this test and evaluation is contained in reference (1).

The manner the ITB conducted its unattended index tests differed from the manner conventional index tests are conducted. The ITB used a feature of the governor to hold power exactly constant. It then caused the blade angle to vary slightly and using signal processing techniques identified steady state conditions before recording a data point. The data was stored on an EEPROM (Electronically Erasable Programmable Read Only Memory) chip that was used to transport the raw data to a separate software program to derive the 3-D cam surface, which was then programmed into an EPROM (Erasable Programmable Read Only Memory) chip. It was intended that there would be one dedicated EPROM chip for each unit and one ITB for each powerhouse. Data reduction was to be done at and by Woodward engineering.

Woodward had acquired a patent on the ITB. An offer by BPA to supply an ITB to the Corps of Engineers for every Kaplan powerhouse was declined in the 1980's. In addition, for unknown corporate reasons, Woodward did not actively market the device. As a consequence of both factors, the ITB fell into a forgotten category. Woodward's Hydro Division was subsequently purchased by GE Energy, Optimization & Control, and in its forgotten category, the patent on the ITB was allowed to expire without being renewed.

INITIAL CONTRACT EFFORTS

In the early 2000's both the Corps and BPA began placing increased value on optimization of hydroelectric generation. Several programs were initiated to increase the efficiency of generation. One of these is referred to as Type 1 or (T1), which stands for the optimization of individual generating units. In particular, this refers to determining the optimum 3-D cam surface to input into the governor to position the blades relative to gate opening and head for optimum efficiency.

A program had been under way for manually indexing one unit of each family of Kaplan units for both with and without fish screens in place. It was realized that an Index Test Box would greatly facilitate that program. Since one had previously been developed, tested, and proven to work without screens, and since the Woodward patent had expired, the inventor of the original ITB was located and contacted. Since the inventor was no longer employed by Woodward, but was in fact an independent contractor, doing business as Automatic Test Equipment Company (ATECo), negotiations were begun to procure a modernized version of an ITB, particularly one using the more powerful and versatile computers now available. Because of the past success in developing a working prototype of an Index Test Box, a sole source procurement process was initiated.

It is noted at this point that this was actually a Research, Development and Demonstration (R,D&D) type of project. The Hydroelectric Design Center (HDC) is authorized by the Corps of Engineers to use research and development type contracts. However, the Portland District, which provides HDC's contract support services, chose to use a construction type contract with which they are more familiar. Further, it was initially drafted as a *firm fixed price* contract. However, due to the proprietary pre-existing technology that ATECo insisted on protecting, this became unworkable and it was switched to a *time & material* contract format.

The sole source justification, government estimate and initial contract work scope are contained in Appendix A. It is noted that this initial work scope provided for government deliverables of: a complete source code listing, parts list and drawings, instruction manual, and the software and hardware to reduce and analyze the recorded test data. It was further specified that the "Type 1 Optimizer," as it was called, was to be capable of being integrated into the existing GDACS (Generic Data Acquisition and Control System) system. In addition, ATECo was to supervise the installation of this first prototype unit, and then was to demonstrate the device by conducting a complete index test and analyzing the data. (It is noted for future reference that GDACS is written in the C++ computer language).

There were several topical areas of a standard construction type contract that had to be addressed and renegotiated with ATECo. One of these was extensive insurance coverage, including Employer's Liability and Comprehensive General Liability insurance. ATECo's insurance agent even interpreted the draft contract to require Product Liability insurance. This latter, especially, would have been prohibitively expensive for this type of R&D effort.

Another was the pre-existing software for the Index Test Box that was considered proprietary by ATECo and for which ATECo acquired a Copyright to document the pre-existing source code. The contract was redrafted to provide executable modules of the source code at a *per each* price and to define the exact insurance requirements for this project.

SIGNAL INPUT

The original ITB was a dedicated testing unit for Woodward's governor and 3-D cam system. It was Woodward's intent that the ITB would spur sales of the 3-D cam by providing an accompanying, automatic, index-testing device as an accessory. This original ITB used its own linear motion transducers for the gate and blade measurement and its own pressure transducers for headwater, tailwater and the Winter-Kennedy piezometer system.

However, in the intervening years, the Corps had developed a generic data acquisition and control system, called GDACS, and installed it in every powerhouse on the Columbia River. This system already contained electronic signal data on the blade, gate, head and power output. Only the pressure differential from the Winter-Kennedy piezometers was not available as a GDACS signal. However, there is a separate program underway to add the Winter-Kennedy differential as an electronic signal to the GDACS.

An index test is not only a relative test, but also a complete system optimization procedure that includes the turbine, generator and powerhouse instrumentation. Therefore, the accuracy of an index test depends, in part, on using the same data signals that are input to the governor for turbine-generator control. Consequently, it was decided early on to have the ITB access the GDACS system to be able to read these data signals. Therefore, since it was intended that the Government would make the data signals available, in Paragraph 3.3.2.1 of the original contract ATECo was required only, "to assess the type and quality of data or signal inputs available from the already installed powerhouse instrumentation." In addition, it was also decided to have the ITB simply send a request signal for the GDACS to reposition the blade angle. ATECo was in favor of these two decisions because it meant the ITB was not responsible for input calibrations and controlling the generating unit during the index test. However, it was subsequently learned that, for security reasons, the GDACS Maintenance Team (GMT) would not allow the connection of any software system for which the Corps did not have a complete source code listing. ATECo, on the other hand, refused to provide the source code for the proprietary, or predeveloped, software modules. Therefore, a substantial amount of time and money on this contract was spent by ATECo in developing an approved way to interconnect with GDACS.

PROPRIETARY SOFTWARE

The longest delay in arriving at a negotiated contract for an Index Test Box had to do with ATECo's pre-developed software code to which ATECo holds a copyright and that the company considered proprietary. This pre-existing code posed an extreme conflict given the security requirements of the GDACS system. Basically, the GMT does not allow any connection into GDACS by any other system to which the Corps does not have the complete source code. However, ATECo adamantly refused to provide the source code to this pre-developed software, but offered instead to provide it in an executable form. This pre-developed code, as well as the co-developed code, was written in Visual Basic 6.0 computer language.

After negotiations which spanned a number of months, an agreement was negotiated and incorporated into Section J of the contract as an Optimizer Special License Agreement. In this section, the Government has only "limited rights" to all contractor pre-developed software and hardware. Under this clause, a contractor may withhold from delivery, data that qualify as limited rights data or restricted computer software, and deliver form, fit, and function data in lieu thereof. In a proposal responding to the solicitation, dated October 14, 2003, ATECo identified the following named subroutines as limited rights data:

- Steady State procedure,

- Parse and Graph procedures,
- Autocal procedure, and
- Registration & Security utility program.

CONTRACT

On May 26, 2004, the contract, contained in Appendix B, was finally signed. The Supplies or Services and Prices of Section B contained three items. The first was the basic time and material procurement for the development and delivery of a prototype Type I Optimizer Index Test Box for $160,000. The second was an option for the hardware and software for up to 320 additional ITB's at $10,667 each and the third was for up to 320 copies of the software only at $2,300 each.

Besides the basic delivery of one prototype ITB, the contract provided for delivery of:

- complete source code listing for any code developed under this contract. Any pre-developed code was to be as a self-contained module and identified by form, fit and function, including inputs and outputs,
- parts list with drawings,
- instruction manual, and
- required software and hardware to reduce and analyze the recorded test data.

The contract further provided that

- only the existing powerhouse instrumentation was to be used by the ITB,
- the ITB was to be capable of being integrated into the existing GDACS system,
- the Contractor was to supervise and participate in the installation, and
- the Contractor was to demonstrate the device by having it conduct a complete index test, both with and without fish screens.

CONTRACT MODIFICATIONS

During the course of this contract, three modifications were issued. The first dated May 31, 2005, contained in Appendix C, included added language that required delivery of any source code written or modified at Government expense. ATECo interpreted this to mean any modifications to his proprietary software required him to deliver the source code to his proprietary software. Consequently, he refused to sign this modification and it did not go into effect. With some language changes, this was reissued as Modification 2, dated July 26, 2005 and is contained in Appendix D. The contract price for Item 1 was increased from $160,000 to $180,000 and the completion date was extended from May 31, 2005 to September 30, 2005. This modification also provided for delivery of an interim design, documentation and software code of an ITB for initial operational testing at McNary.

The third modification, contained in Appendix E, was necessary due to time and effort required by ATECo to try and comply with the Government's verbal change orders. It increased the contract price from $180,000 to $196,002 and extended the completion date from September 30, 2005, to January 9, 2006. It also contained a number of changes to the work scope, including that:

- the format of the pre-developed code in the Revision 1 v 3 dated 5 Dec 05 is acceptable and satisfies the modular contract requirement,

- the unit will be tested either with or without fish screens in place, but probably not both, and
- for security reasons, only Government personnel are to install and operate the ITB.

SELECTED PROJECT

The project selected for the demonstration of the Index Test Box was the McNary powerhouse. This was chosen for three reasons:

- the units had 3-D cams,
- the project utilized fish screens during the downstream migratory season, and
- there exists a history of index tests at this project, particularly on unit #5.

INITIAL PROBLEMS AND PROGRESS

The majority of the work effort, both by ATECo and HDC under this contract and its modifications, has been related to the interface and incorporation of the Index Test Box with and into GDACS.

One of the initial attempts to facilitate this interface was a contract requirement for a demonstration of the ITB as an independent bench test. A mockup, comprised of samples of all the components used in the GDACS system, was assembled as part of the 3-D cam development program. This mockup had a SoftPLC computer, MTL I/O modules, and a stepping motor driven 2-D cam output mechanism. A SoftPLC is a Programmable Logic Controller, a dedicated type of computer, made by SoftPLC Company. A MTL I/O is an input/output signal interface manufactured by the MTL Corporation that plugs into the SoftPLC to provide the analog to digital signal interface for GDACS. However, when located in a storage room of the GDACS contractor, Automatic Control Systems Incorporated (ACSI), this mockup was in state of disarray and disassembly. In addition, no documentation on this mockup could be located. As a consequence of its unuseability, the design of the ITB was changed to use a simulator fabricated by the ATECo.

The governor of unit #5 was originally retrofitted with a 3-D cam made by the Seawell Company. The Seawells were replaced with a stand alone, SoftPLC based, 3-D cams developed by HDC starting in year 2000. Technically known as NWP 3-D cams (Northwestern Division, Portland District) these were installed on the units as they were brought offline for scheduled outages. However, photographs taken at the project showed that the NWP 3-D cam was no longer on the governor of unit #5. Instead the software code for the 3-D cam had been installed in a PLC in the GDACS. This system was now called NWPR 3-D where the R stood for “regional.” However, the Panelmate, which displayed the NWP 3-D parameter values, was left operational to display the same values from the GDACS PLC. This change to the regional cam prevented ATECo from doing a complete, planned equipment survey during his first visit to the project. It was reported by the project that the stand alone 3-D or NWP 3-D cam would be reinstalled on unit #5 in about two weeks

In order for the ITB to communicate with the stand alone 3-D cam, ATECo was directed by the Contracting Officer’s Technical Representative (COTR) in HDC to use, as government furnished equipment, a TOPDOC software-programming environment from SoftPLC. This was to be used to modify the “C” programming language code in the

Soft PLC 3-D cam to get it to communicate via standard RS-232 ports with the ITB. It was subsequently found that there was no source code in the SoftPLC to edit.

ATECo was then directed by HDC to use the Ethernet-based Object Linking Environment (OLE) for Process Control (OPC) communication method to interface the ITB to the SoftPLC. However, prohibitions by the GMT for security reasons prevented HDC from physically connecting the ITB to the GDACS network, and this, in turn, precluded HDC from giving ATECo the data tag names for the GDACS 3-D cam.

It was then learned that the stand alone NWP 3-D Soft PLC 3-D cam would not be reinstalled for a couple of months. A short time later it was learned that it would not be reinstalled at all. The software code for the NWPR 3-D cam that was installed in a PLC in the GDACS was going to remain. This exacerbated the security issue with the ITB for now it needed to communicate directly with GDACS. When the ATECo reported this configuration control difficulty to the Contracting Officer, the Stop Work Order of Appendix F, was issued on October 14, 2004. A restart order was issued on October 25, 2004.

When work resumed, ATECo was then directed by HDC to use the RSLinx OPC software from Rockwell. After purchasing both versions, RSLinx OEM (Original Equipment Manufacturer) and RSLinx SDK (Software Designer's Kit), it was found that neither version supported Visual Basic, the software language used by the ITB. The two Rockwell RSLinx servers were returned to the manufacturer for a refund, which was reimbursed to the contract's project budget. ATECo then unilaterally switched to Software Toolbox's TopServer, which allowed the project to continue.

ATECo finally provided a Purchase Order to ACSI on March 24, 2005, for $1,000 and bought the OPC tag-names and configuration information for a GDACS connection. With that information, he was finally able to make the OPC connection to the SoftPLC work.

Once communication was established, the remaining functional item was the movement of the blades. It had been intended from the beginning that the ITB would only send a "request" for GDACS to effect a small movement or "perturbation" of the blades. A Task Order, contained in Appendix G, was issued to ACSI by HDC to modify the software code in GDACS to perform this function. However, there was insufficient time before the first field test to coordinate this feature between the ITB and GDACS. Consequently, ACSI had to modify the GDACS code in the field the morning of the first test.

FIELD TRIPS AND TESTS

In the last week of August 2004, ATECo traveled to HDC in Portland for a scoping meeting and then to McNary for an equipment survey. A primary objective of the equipment survey was to determine a workable location for access into GDACS. This access point could not be determined at that time. A detailed trip planner and trip report are contained in Appendix H. At the project, the Contractor was provided with a working Soft PLC and Panelmate to take back to his home office.

In May, 2005, the hardware and a version of the software for the Index Test Box were delivered to HDC. No documentation or any kind of manual accompanied this delivery. During development of the Perturbation function on the test bench in the GMT facility, a software bug was found that became known as the "zero problem." The

GDACS software has a failsafe "Watch Dog" timing subroutine. Whenever a blade command is not received at least every ten (10) seconds, the Watch Dog sets a zero for the blade "Perturbation On" bit, in order to return the unit to on cam operation. That particular release of the ITB software, Release #16, had a "bug" that, under certain circumstances, allowed a zero to be erroneously sent as the "Perturbation Offset" value. ACSI programmed a "fix" into the GDACS software named the "zero snatcher." With this fix, whenever a zero appeared in the blade angle bias window, it was immediately snatched away. This fixed the initial problem but created another problem. Now the GDACS Perturbation function would be disengaged whenever the ITB requested the unit to be at the "on cam" position in order to record performance data. Although ATECo sent a later revision with the zero problem removed in advance of the scheduled field test, Revision #16 was the release that had been subjected to GDACS security testing and therefore was the version taken to McNary for the first field test.

As documented in the trip report in Appendix I, in the second week of August, 2005, unaccompanied by any ATECo representative, HDC personnel transported the ITB to McNary. The Winter-Kennedy piezometers were plumbed, valved, and connected to an electronic transducer. The output of this transducer was fed into ATECo's "signal conditioning box," designated ATE-150. It was intended that this box would be used with the automatic flushing system, still to be developed for the Winter-Kennedy piezometer system. However, at present, it only served to provide a full range signal from the transducer of 4 to 20 milliamps into the ITB. After connecting the ITB into GDACS, the HDC personnel sought to operate it to record performance data. However, due to a broken wire in the prototype ATE-150, a signal from the Winter-Kennedy's for the relative flow measurement could not be obtained and only power-gate data could be recorded. After this first try at a field test, the signal conditioner was returned to ATECo, where the problem of the internal broken wire was immediately found.

In September, Revision #21 was received which incorporated many of HDC's comments resulting from the attempted field test the month prior. After having been tested on the GMT test bed at HDC to meet GMT security requirements, the ITB was again taken to McNary and installed on unit #5. Then, during the second week in September, this time accompanied by ATECo's representative, preliminary test data was collected both at near constant power settings and at variable power settings.

As the data was being recorded, a check disclosed a discrepancy in the Winter-Kennedy piezometer data compared to the same data from a previous manual, index test. The piezometric differential was much less, at the same power levels, than for the previous index test. This lower differential was independently verified by a water manometer. The project construction drawings were checked to verify that the correct Winter-Kennedy piezometer valves were connected to the transducer and water manometer. It was theorized that one of the embedded piezometer lines was ruptured and that leakage prevented the correct differential from being recorded for a given flow rate. Later, during the December field test, a reading on the water manometer with the unit shut down showed a zero differential, indicating there was no leak. It was later found that, in fact, the low deflection, inner piezometer valve had been connected to the transducer. It was then found the project construction drawings were known to be in error from previous index testing, but had never been corrected. Sufficient data was recorded to verify operation of the ITB. The trip report for this field test is contained in Appendix J.

During this test, an aspect of the unit's control or governor dynamics became evident. It had been originally intended that this new ITB would operate in the same manner as the original ITB of 20 years ago. That is, it would record data as the blades were perturbated while the unit remained at constant power. It was found that a significant amount of time was required to attain each MW setting within about 0.2 MW. First, the governor took about 8 minutes to settle out each time a control action occurred. In addition, it took about 20 minutes to get to a predetermined MW setting. Further, the smallest MW control resolution seemed to be about 0.3 MW. These factors resulted in a significant scatter in MW values, rather than performance data being recorded at constant generation levels.

In the second week of December, 2005, Revision #31 was received at HDC and installed in the GDACS test bed. This was the "best and final" version of the software and was the version to be subjected to the "proof of concept" testing on unit #9 at McNary. It had already been decided to shift the test unit from #5 to #9 when the deflection anomaly of the Winter-Kennedy piezometers was first noted. Also, given the MW scatter of the previous field test, it was hoped that that a different governor would allow performance data to be gathered at constant power.

The demonstration test did prove the concept of the ability of an Index Test Box to conduct automatic, unattended index tests on Kaplan turbines. However, even accompanied by two of the ATECo's representatives, difficulties were encountered and work certainly remains to be done before an ITB is useable on a regular, operational basis. The following extracts from the Conclusions of the trip report in Appendix K provide a bulletized summary:

- "The ITB interfaces well with existing government equipment to collect the necessary data."
- "The ITB as tested is not yet capable of conducting index testing in a fully automated, unattended fashion. Intermittent software glitches cause the program to crash."
- "It is anticipated the software bugs which caused intermittent program crashes will be identified and corrected. This being the case, the ITB should then be capable of unattended, automated data logging of 'steady state' turbine operation."
- "Over any length of time, a tremendous amount of data will be logged over the entire large operating range. A significant effort will be needed to sort and reduce this data."

In addition to problems with the ITB, the dynamics of the governing system exacerbated the testing difficulties. This unit not only had difficulty in maintaining constant power, it also exhibited excessive "hunting" in reaching a giver power value. In addition, the blade angle positioning had a dead band error of plus and minus one degree programmed into the NWPR 3-D cam. For security concerns the ITB was constrained to allow a maximum perturbation of only plus and minus two degrees off cam. These factors meant the window in which performance data could be recorded was quite narrow.

In the second week of February, 2006, the ITB was transported to Ice Harbor where units #3 and #6 were index tested by conventional techniques. The ITB, containing software Release #43, was connected to record data only, without the blade perturbation feature being activated. A fairly small quantity of data was available to be recorded and that which was recorded was noisy, particularly the Winter-Kennedy relative flow data. However, ATECo was able to successfully reduce this data and render a graphical presentation. This plot showed that the limited blade stroke did not provide for the "cresting over" of the efficiency, sufficient to develop a cam curve to a high degree of accuracy. The trip report memorandum in Appendix L noted:

- "As far as proof of concept, its clear ITB is capable of collecting the data necessary to develop cam information. The major deficiencies identified from McNary test of ITB (system crashes and streamlining of data logged) have been addressed."

DATA REDUCTION

Historically, normal index performance data has one more degree of freedom than can be reduced by traditional methods. That is, when blade, gate, power and efficiency are independent parameters, there are one too many variables to be graphically plotted on a Cartesian coordinate system. In order to reduce the independent variables to three, a manual index test is performed at a series of constant or fixed blade angles. Similarly, the original ITB conducted automatic index tests at a series of constant power levels. Because of those precedents, Paragraph 1.7.2.5 of the basic contract specified ATECo is to provide, "Any required software and hardware to reduce and analyze the recorded test data and present the results in a standard format." The format used by the data reduction of the original ITB was a series of skewed, concave downward, constant power curves on a Cartesian plot with gate opening as the X-axis and blade angle as the Y-axis. On such a plot, it was fairly easy to construct the closed, circular contours of the isoefficiency lines to form a type of hill curve. Then the "ridge runner," or the line of peak efficiency, could be constructed which was simultaneously the blade to gate cam curve. From this, the profile of efficiency versus power could be constructed.

However, given the present governing system, with its dead bands and inability to maintain constant power with a change in blade angle, there is no way to reduce the number of independent performance variables by being able to hold any one of them constant. Consequently, at one of the weekly "partnering," conference calls, it was agreed that ATECo was to still provide the data reduction software for data recorded at constant power levels, but HDC was responsible to provide a means of reducing data where no parameter is held constant.

ATECo's attempt to reduce this data from McNary unit #9 by using selected points recorded within narrow power bands, the same as though they were taken at constant power levels, is contained in Appendix M. This test report memo noted:

- "Some scatter in power level in the data was unavoidable due to these equipment constraints, causing noticeable distortion of the constant generation lines on the graph."
- "Due to the insufficient data available for a high confidence data reduction, HDC agreed to an extrapolation of the available data to demonstrate the reduction technique."

- "Despite these problems, the actual and extrapolated data in the graph is satisfactory to demonstrate the cam surface definition procedure."

This type of data reduction problem, with all of the performance parameters being variable, has been addressed several times in the past by other data recording systems. Basically, what is required is a three-dimensional graphical plotting routine. A number of years ago a computer program at Bonneville Power Administration (BPA) was adapted for this purpose. This was a topographical plotting program used to calculate the amount of cut and fill for substation construction. All that was done was to input gate opening as longitude, blade angle as latitude, and efficiency as an elevation. This program was successfully used to reduce a number of index test data sets on Corps of Engineers units. Most recently, with the data from McNary unit #5, a hydrographic plotting program within the Hydrology Section of the Portland District of the Corps of Engineers was tried out. This showed definite promise as a possible method of reducing this type of data. In addition, a software program named GNUPlot, available for free on the Internet, was down loaded and tried as index data reduction software. It also showed promise. ATECo has also been experimenting with a commercial software program named "Statistica" from StatSoft Company and the 3-dimensional graphing routines in National Instruments' "Visual Studio 8." However, given the recent advances in specialized computer software, it was decided to prepare a solicitation to competitively procure custom designed software for data reduction and graphical presentation of index test data where all performance parameters are variables. A draft of this solicitation is contained in Appendix N.

WINTER-KENNEDY PIEZOMETER SYSTEM

In ATECo's original pricing proposal, the costs of several transducers to measure head, gate, blade and flow were included. With the decision to monitor the signals in GDACS, these transducer costs, with a single exception, were eliminated in the initial contract negotiations. The exception was a differential pressure transducer to measure the pressure differential between the two Winter-Kennedy piezometers. This differential is a function of the flow rate and its measurement is used as a value for relative flow. This relative flow is the one performance parameter that is not presently available in GDACS. A program has been formulated to install transducers on the Winter-Kennedy's in the future and input those signals into GDACS. However, for the present demonstration of an Index Test Box, this transducer was left in the contract.

In order to be consistently accurate, the Winter-Kennedy piezometers should be bled down periodically when in use. Typically, this should be done at least every four hours during an index test. The purpose is to prevent the build up of bubbles from dissolved gasses coming out of solution and to retain the water temperature in the piezometer lines the same as in the spiral case so that the specific weight of water between the two remains the same. For purposes of demonstrating the Index Test Box, it had been planned to simply bleed the Winter-Kennedy's manually. However, the COTR verbally issued a constructive change order to ATECo to design and furnish an automatic flushing system. Later, when work on this change order was interfering with field test schedules, the change order was rescinded. Therefore, the use of any future ITB on a regular, operational basis will need to be accompanied by the development of an automatic Winter-Kennedy piezometer flushing system.

LEGAL ASPECTS

The technical complexity of this project and the fact that significant proprietary rights in both software coding and technical data are involved have led to several matters that have been referred to Corps' general counsel. ATECo has filed formal complaints with both Inspectors General (IG) of the Department of Energy (USDOE) and the Department of Defense (USDOD). A copy of the complaint documentation to USDOD is contained in Appendix O.

Second, there have been three separate requests for information from ATECo under the Freedom of Information Act. These are:

1. ATECo requested the GDACS and ACSI's 3-D cam and "Zero Snatcher" software programs. The government's response, contained in Appendix P, was a denial citing that the requested software is not a "record" under FOIA. The Government's response further cited that, "For valid security reasons, these operating programs are protected by the government and are not being released to the public, subject to the memoranda from the Homeland Security Office."
2. ATECo requested to know the status of the complaint filed with USDOE. The response from USDOE's IG, contained in Appendix Q, was to withhold such information since, "no final determination concerning this investigation has been made." The response further noted, "Release of the withheld material at this time could prematurely reveal evidence and interfere with the ongoing enforcement proceeding."
3. The third request was for, "a copy of all ITB Project test data, field reports and conclusions; i.e. memoranda and/or letters, test data, test reports and management responses relevant to field testing of my ITB product in December 15, 2005 at McNary Dam and again in February 6, 2006 at Ice Harbor. Also please send any overview and/or conclusions about compatibility issues of ITB to GDACS, and the criteria upon which this determination of compatibility was made." This request was submitted to the Portland District, which forwarded it to the Walla Walla district. Walla Walla subsequently returned it to Portland for action. The Portland District then denied ever having received the request.

FUTURE PLANS

The proof of concept of an Index Test Box that can automatically conduct an index test on a Kaplan turbine has been successfully demonstrated. The next step is to put this technology into practice. A proposed plan of implementation for this current fiscal year and beyond is contained in Appendix R. Basically, it proposes to complete evaluation and testing by purchasing two additional ITB's under the option clause of the existing contract. There would be a specific purchase order, including some changes to the software that had been found desirable during the previous field tests. These changes are delineated in the trip reports in the appendices. One ITB would be purchased to be permanently installed in the GDACS system of a multiunit powerhouse. The second would be supplied with its own transducers to be permanently installed in a non-GDACS powerhouse.

After that, the consensus opinion is to contract with another contractor to develop a "production version" of an ITB for installation in all Corps' powerhouses throughout the Pacific Northwest. However, there are two different schools of thought on how to solicit proposals to produce this production version. One school opts for a procurement contract in which a specified number of the new production versions of the ITB are a contract deliverable. The second school opts for the procurement of a contractor's services to work under supervision of HDC to design, develop and manufacture the production version of the new ITB. In either event, it is presently planned to prepare a solicitation for the second choice in which the production version ITB's are developed under HDC supervision. The data reduction software will be included in this solicitation. However, the automatic Winter-Kennedy flushing system will be developed under a separate work scope.

LESSONS LEARNED

Usually this type of report is ended with a paragraph on recommendations and conclusions. However, this is a report of an on going program effort. Therefore, the merit in such a report is in the "lessons learned," such that hopefully, any mistakes will not be repeated in future efforts. With that as a guideline, the following lessons are noted:

- This is really a research, development, and demonstration (R, D & D) type of effort on the part ATECo. The contract should have been a research type of contract, rather than a construction type.
- The development of a modern Index Test Box and its integration into GDACS should have been kept separate. A generic, stand alone ITB should have first been developed and demonstrated. Any errors due to separate transducer signals from those of the transducers utilized by GDACS should have been accepted. This would also have resulted in a non-GDACS version of the ITB already being developed. Only then, should there have been a completely separate contract to integrate the ITB into GDACS.
- Only written change orders that are signed by the Contracting Officer should have been issued to ATECo.
- This project suffered continuously from a lack of documentation from ATECo. A contract should be very specific as to the content and format of the documentation and its delivery schedule to the Government.
- The dynamics of the governing systems of the selected test units differ from industry standards. These dynamic and governor performance characteristics should be listed in any future contract.

REFERENCES:

(1) "Manual Index Test of Portland Hydro Plant #2;" Final Report; Portland General Electric and Generation Programs Branch, Bonneville Power Administration; May 1988.