CITY OF WEST UNIVERSITY PLACE

2021 WATER SYSTEM ASSESSMENT

TECHNICAL MEMORANDUM APPENDICES A - H

PREPARED FOR:

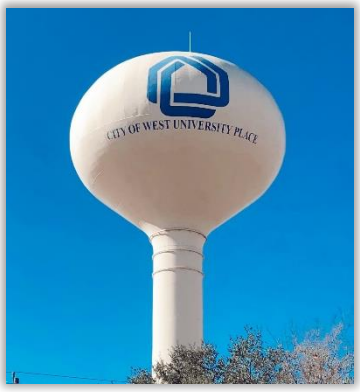
City of West University Place

PREPARED BY:

Freese and Nichols, Inc.
11200 Broadway St., Suite 2320
Pearland, Texas 77584
832-456-4700

FREESE AND NICHOLS

City of West University Place



APPENDIX A
Well Pump Performance Test Reports

August 27, 2020

City of West University Place
Attn: Mr. Chad Smith
West University, Texas 77401

Reference: Water Well #8 – Milton Street

Dear Mr. Smith,

Collection and evaluation of field data pertaining to the operation of the well and well pumping equipment was recently completed at the above referenced facility. Included in this report please find the test results and pump curve generated by the testing.

PERFORMANCE TEST REVIEW

Hydraulic Performance of pump is 1674 GPM @ 348' field head	Excellent ___	Good __X__	Marginal_____	Poor____
Overall efficiency is 62 percent	Excellent ___	Good__X__	Satisfactory _____	Poor
Pump Submergence 260 feet	Excellent __X___	Good ____	Marginal____	Poor_
Vibration Analysis	Excellent __X___	Good ____	Marginal____	Poor_
Suspended Solids Testing	Excellent __X___	Good____	Marginal____	Poor___
Brass Observed in SST	None _____X___	Trace_____	Substantial ___	Excessive__
Flowmeter Accuracy is 100.8 percent				

The test indicated that the pump appears to be operating in satisfactory condition.

We appreciate this opportunity to be of service. If you have any questions or comments, please call.

Sincerely,
Gary McMurrey

G-M SERVICES

SPECIALIZED INSPECTION SERVICES FOR THE WATER INDUSTRY

Performance Test Report

website: www.g-mservices.com phone: 281-894-8971

Facility City of West University Place - well #8 **Test Date** 08/25/2020

U.S.G.S. # LJ-65-xx-008 **Subsidence Well ID#:** 3768

PUMP DATA

Manufacturer :	American
Bowl Type :	15-M-180
Stages :	5
Setting :	580
Column Size :	10" x 3" x 1 15/16"
Design Point :	1600 GPM @ 432. TDH

MOTOR DATA

Manufacturer :	General Electric
Size (HP) :	300
Amps/Volts :	362/460
Serial # :	60127828
Frame :	L449TP20
Speed (RPM) :	1785

PERFORMANCE TEST DATA

Static Lvl (ft) -235

Discharge Pressure	12	12
Capacity (GPM)	1674	1674
Pumping Lvl (ft)	-320	-320
Drawdown (ft)	85	85
Specific Capacity	19.69	19.69
Field Head (ft)	347.72	347.72
Water Horsepower	146.9	147.14
Overall Efficiency	62%	62%
Horsepower Input	235.44	235.44
Kilowatt Input	175.7	175.7
Amp Draw	258-258-247	258-258-247
Voltage	468-465	468-465
Sand (PPM)	2	2
Time (min)	45	45

Meter Data

Manufacturer: Water Spec Size: 12

Serial #: 20200898

Meter Read: 045445.000

Meter accuracy is 100.8 % at 1687 GPM

Additional Data

Start-up Sand (PPM)	6
Brass Detect:	No
Pump Submergence (ft)	260
ETM Read:	

Remarks

New meter installed.

Vibration analysis completed.

TECHNICIAN R McKissick

AMERICAN TURBINE

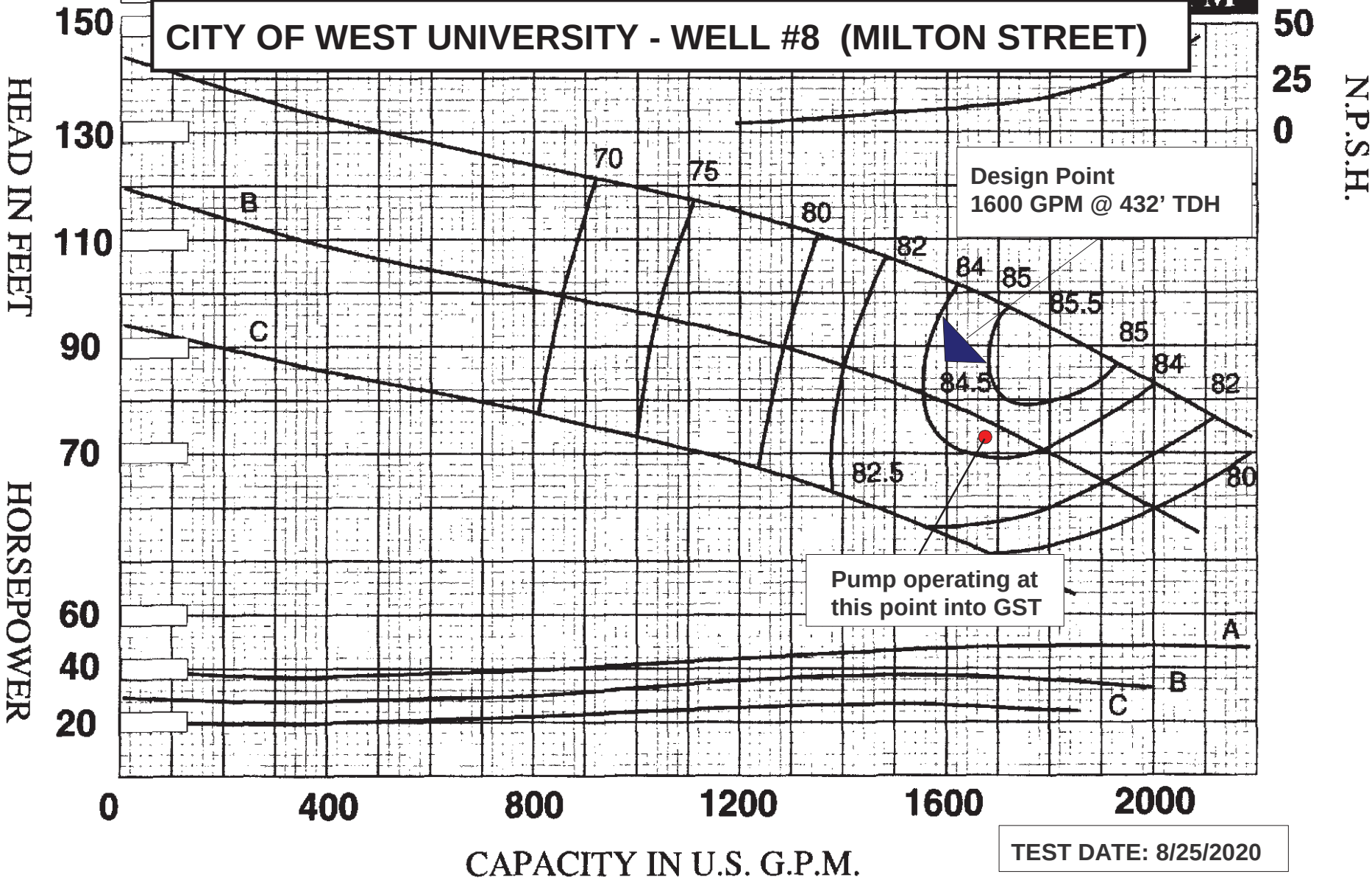
Performance Curves

15-M-180

1760 RPM

Number of Stages Required:

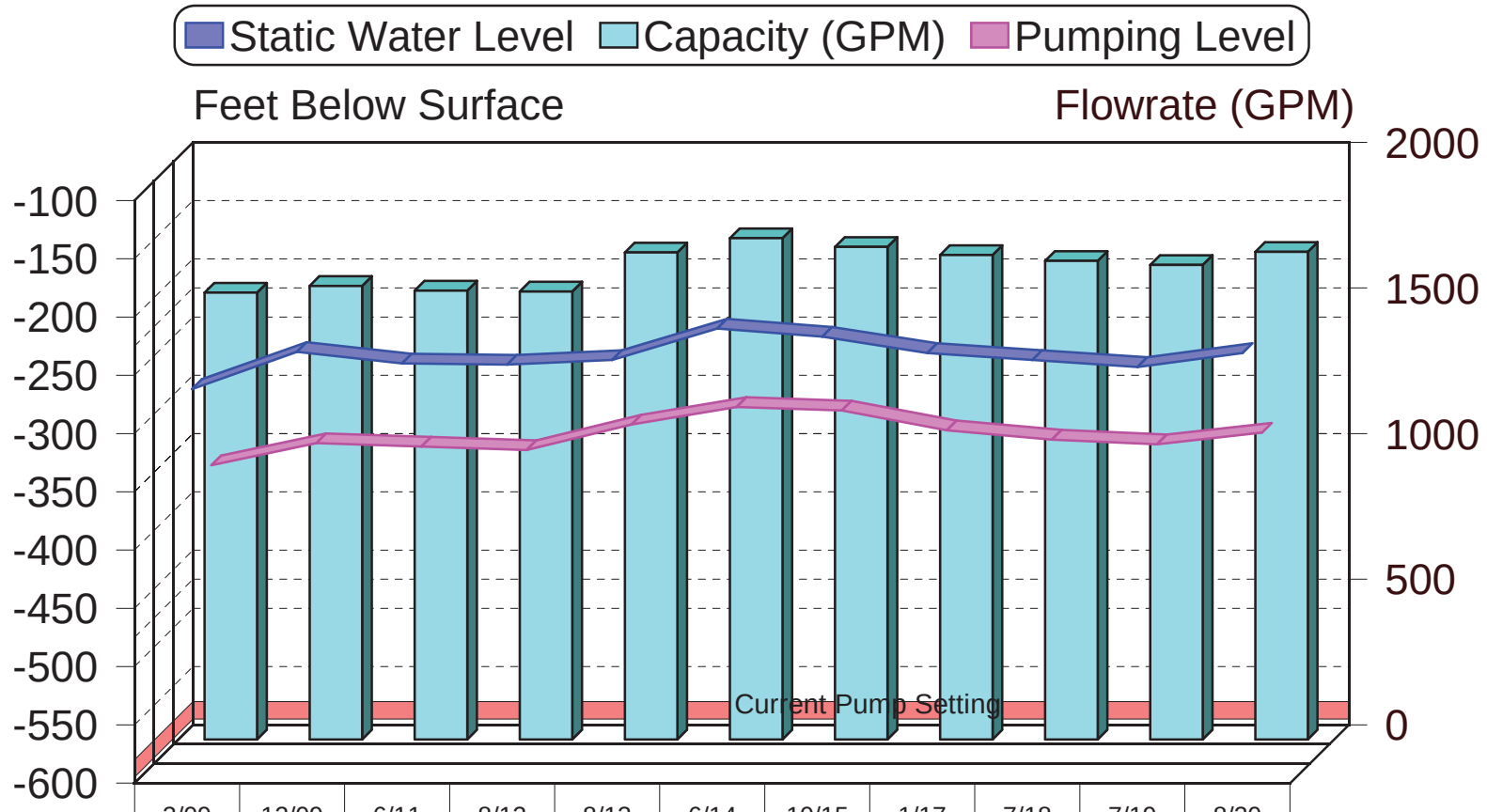
CITY OF WEST UNIVERSITY - WELL #8 (MILTON STREET)



TEST DATE: 8/25/2020

City of West University Place

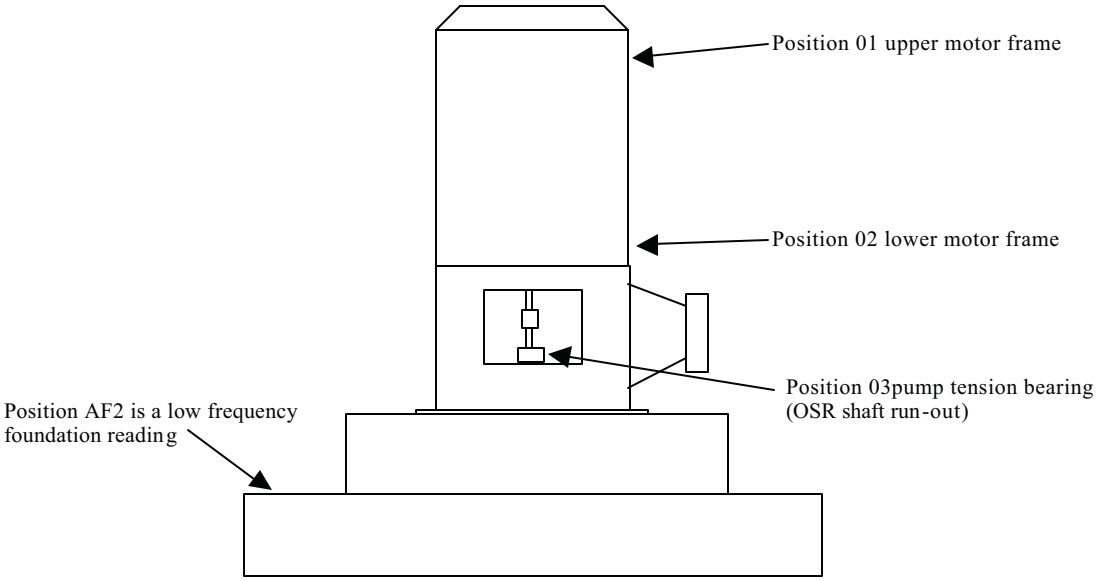
Well #8



	3/09	12/09	6/11	8/12	8/13	6/14	10/15	1/17	7/18	7/19	8/20
Static Water Level	-266	-234	-244	-245	-241	-214	-221	-235	-241	-247	-235
Capacity (GPM)	1534	1557	1541	1538	1672	1721	1691	1663	1643	1629	1674
Pumping Level	-348	-329	-332	-335	-313	-298	-301	-318	-326	-330	-320

Prepared by G-M Services

VIBRATION ANALYSIS DATA
TYPE 3 Machine



Explanation of vibration Identification System

First digit is measurement location	Second digit is direction
01 = upper motor bearing	1 = horizontal
02 = lower motor bearing	2 = vertical
03 = pump tension bearing	3 = axial

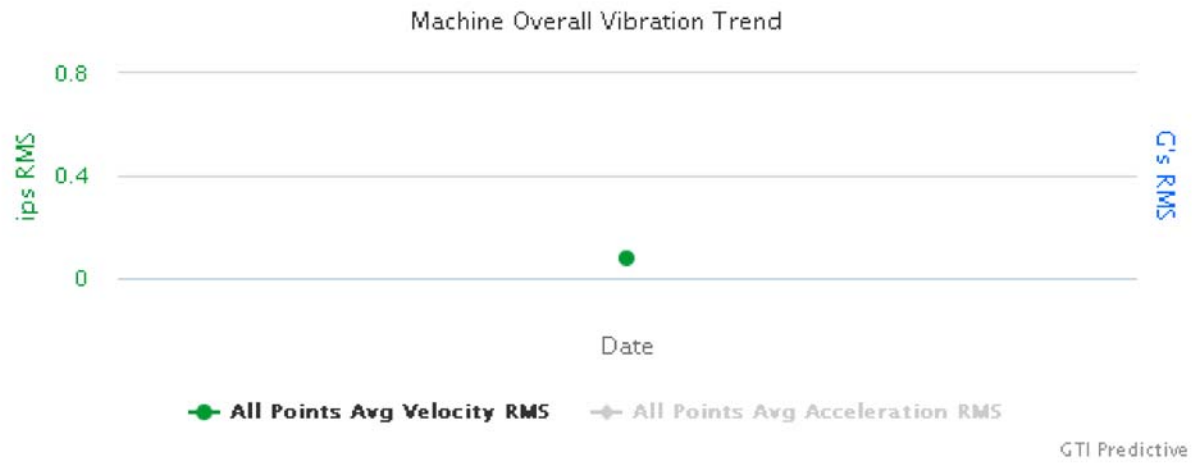
Example: Position 022 is the lower motor bearing vertical direction.
Position 031 is the pump tension bearing horizontal direction.

Measurement points are taken at each bearing. The points are numbered starting at the driver and ending at the driven end.

Note: Position AF2 is an acceleration reading on the pump foundation (axial position)
Position OSR is a shaft rider reading at the top of the tension bearing.

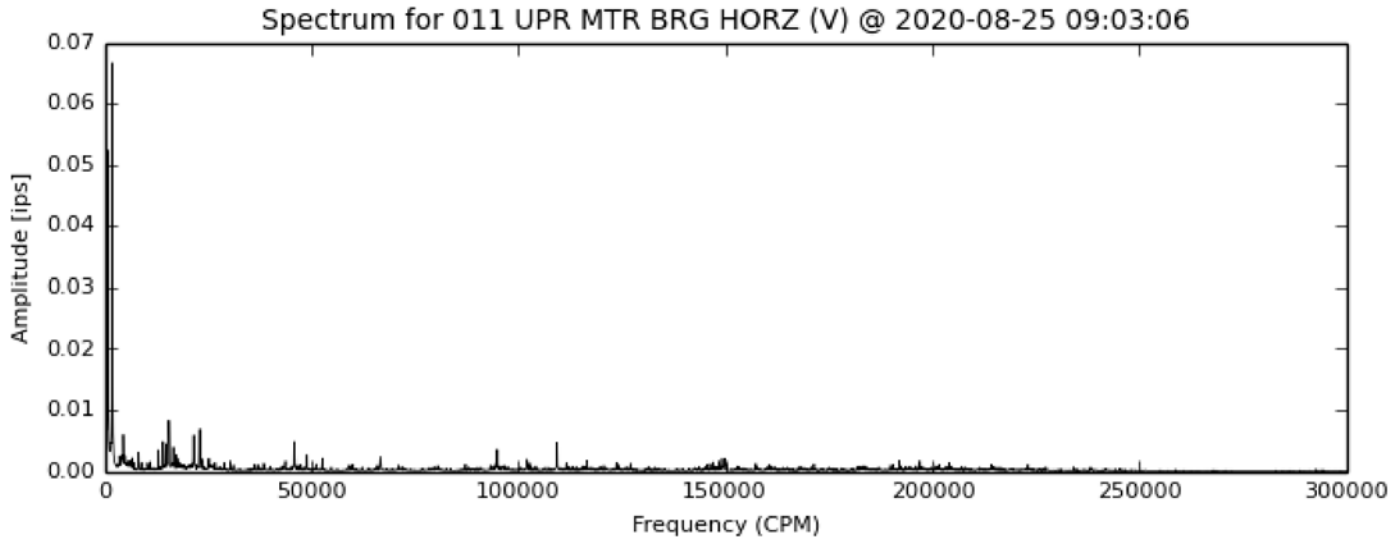
MACHINE REPORT
Report Date: Mon, Aug 31. 10:05:46 am EDT

Plant/Area: CITY OF
Machine name: WEST UNIVERSITY WW 8



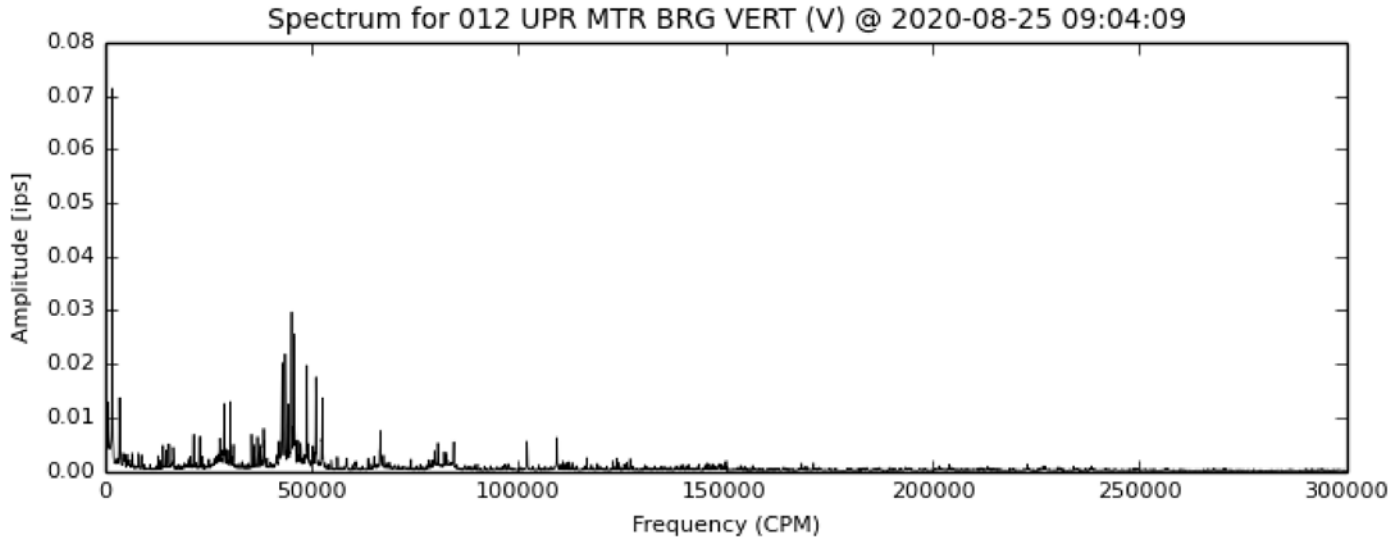
POINT: 011 UPR MTR BRG HORZ (V)

Date	RMS	Severity
2020-08-25 09:03:06	0.1027 ips	GOOD



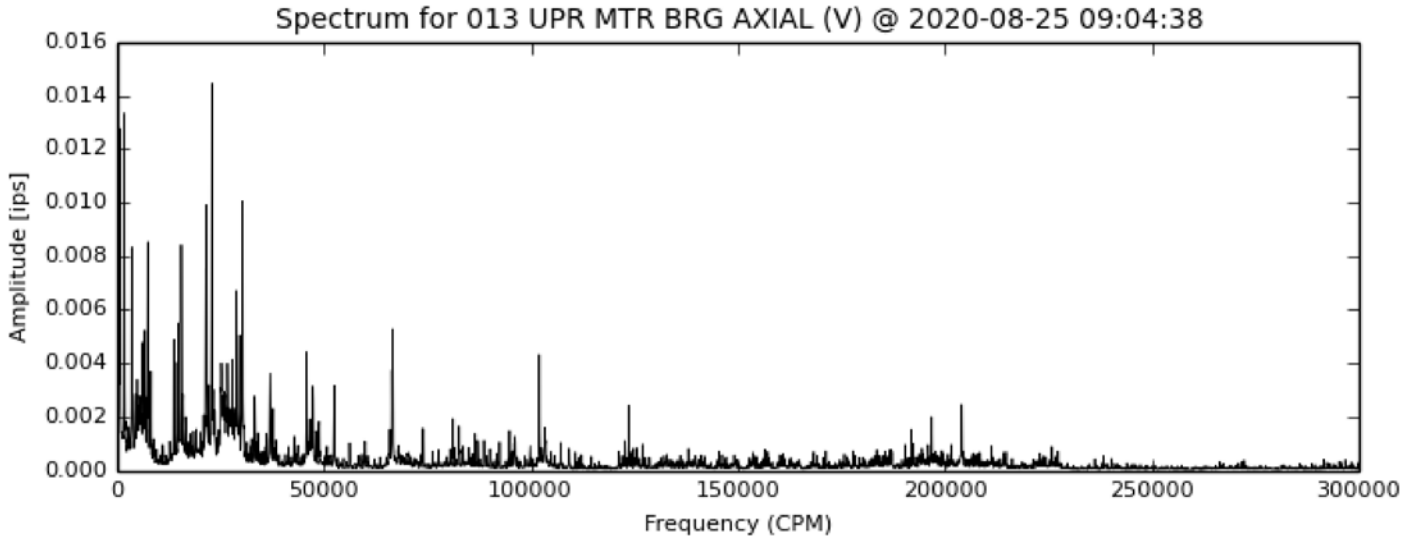
POINT: 012 UPR MTR BRG VERT (V)

Date	RMS	Severity
2020-08-25 09:04:09	0.1299 ips	GOOD



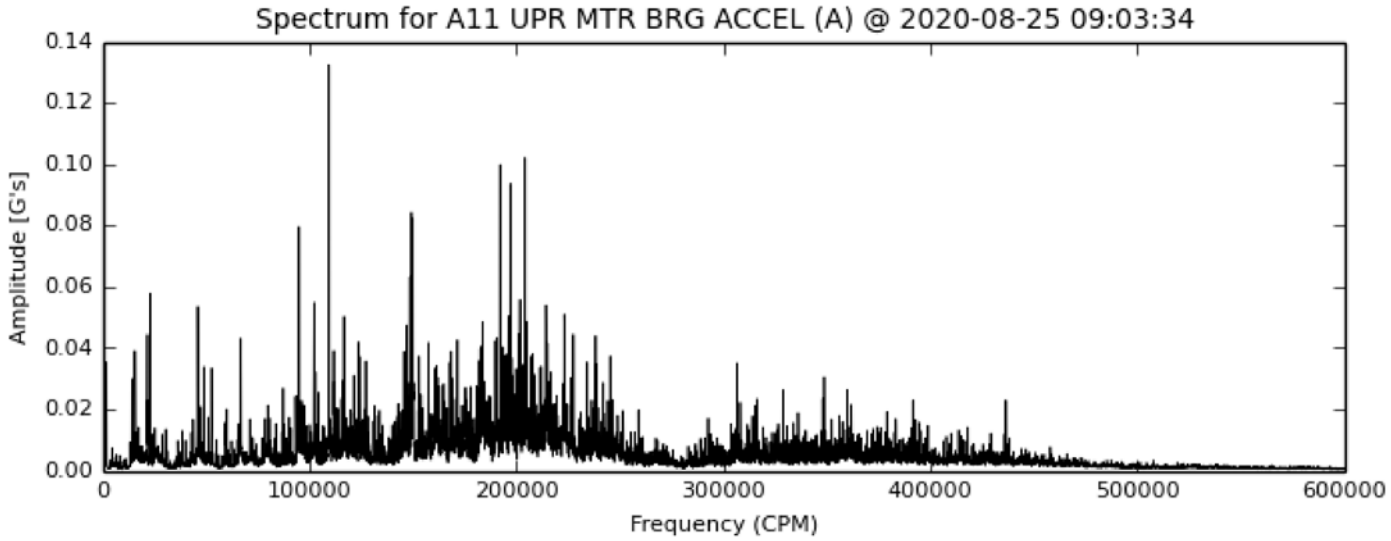
POINT: 013 UPR MTR BRG AXIAL (V)

Date	RMS	Severity
2020-08-25 09:04:38	0.0558 ips	GOOD



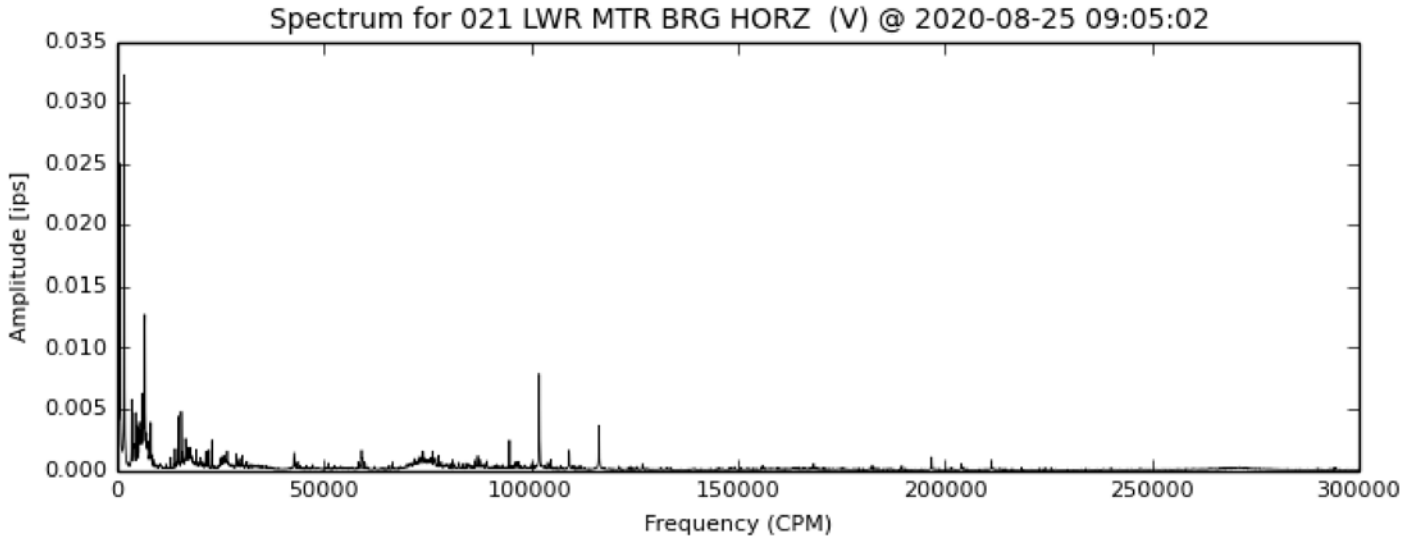
POINT: A11 UPR MTR BRG ACCEL (A)

Date	RMS	Severity
2020-08-25 09:03:34	0.746 G's	GOOD



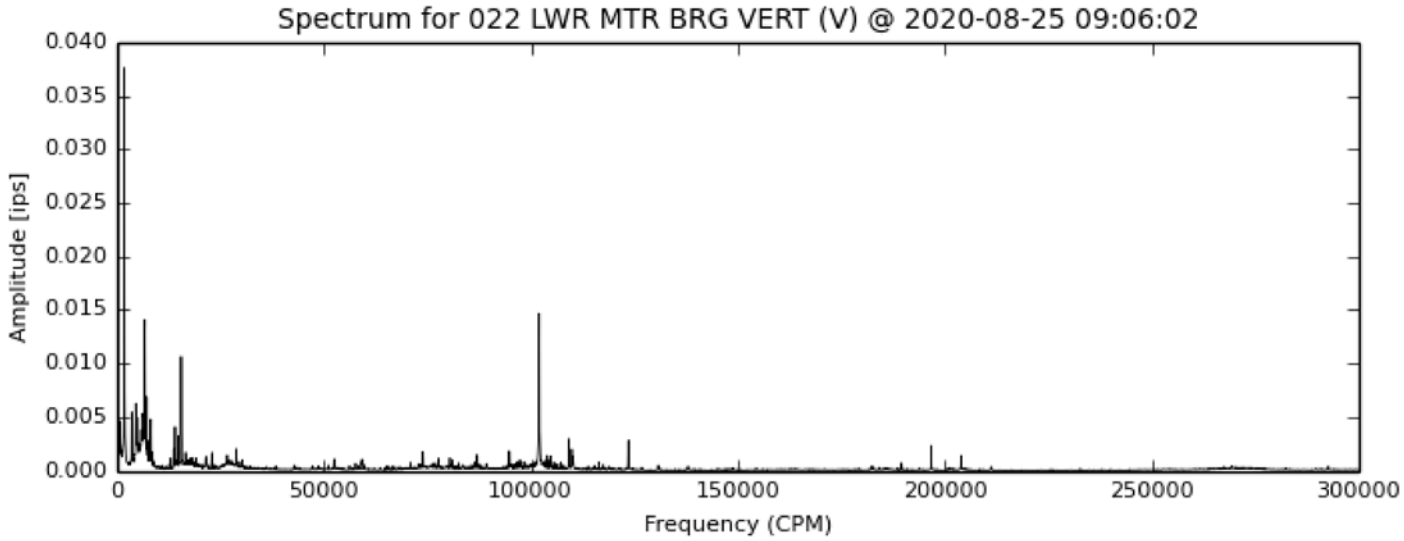
POINT: 021 LWR MTR BRG HORZ (V)

Date	RMS	Severity
2020-08-25 09:05:02	0.0581 ips	GOOD



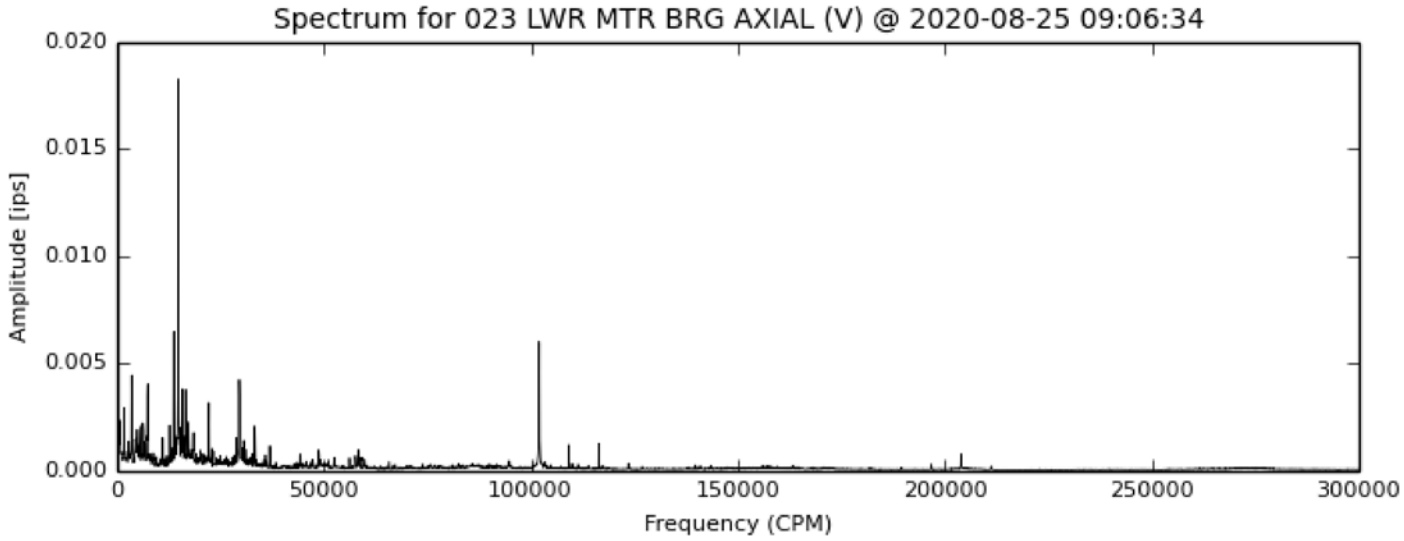
POINT: 022 LWR MTR BRG VERT (V)

Date	RMS	Severity
2020-08-25 09:06:02	0.0577 ips	GOOD



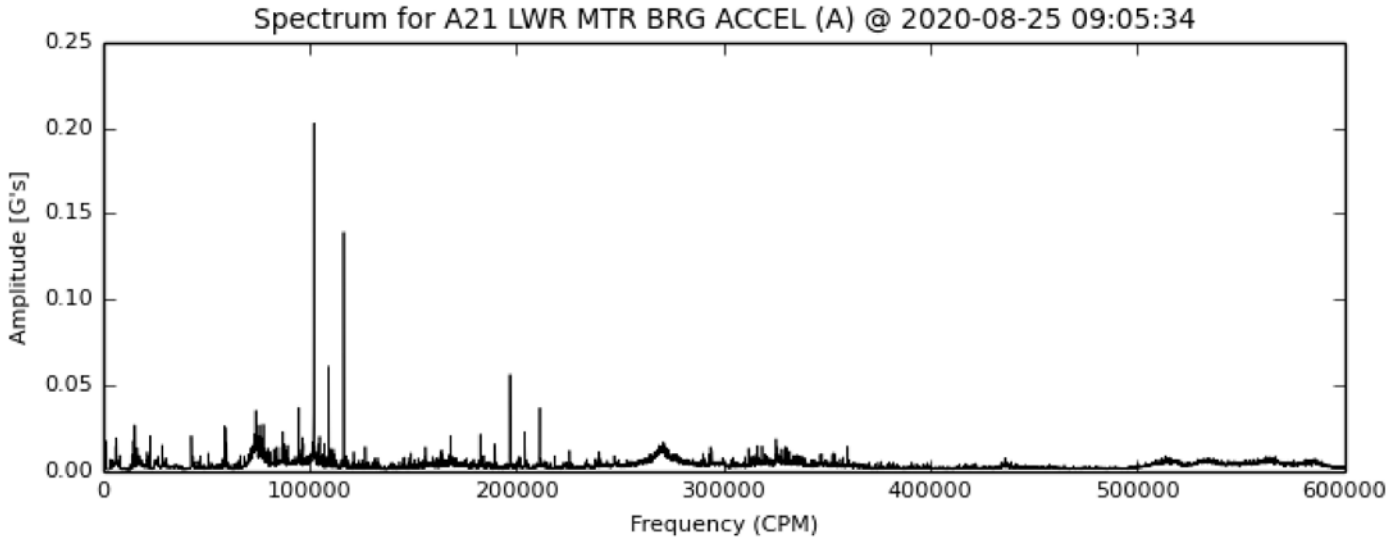
POINT: 023 LWR MTR BRG AXIAL (V)

Date	RMS	Severity
2020-08-25 09:06:34	0.0308 ips	GOOD



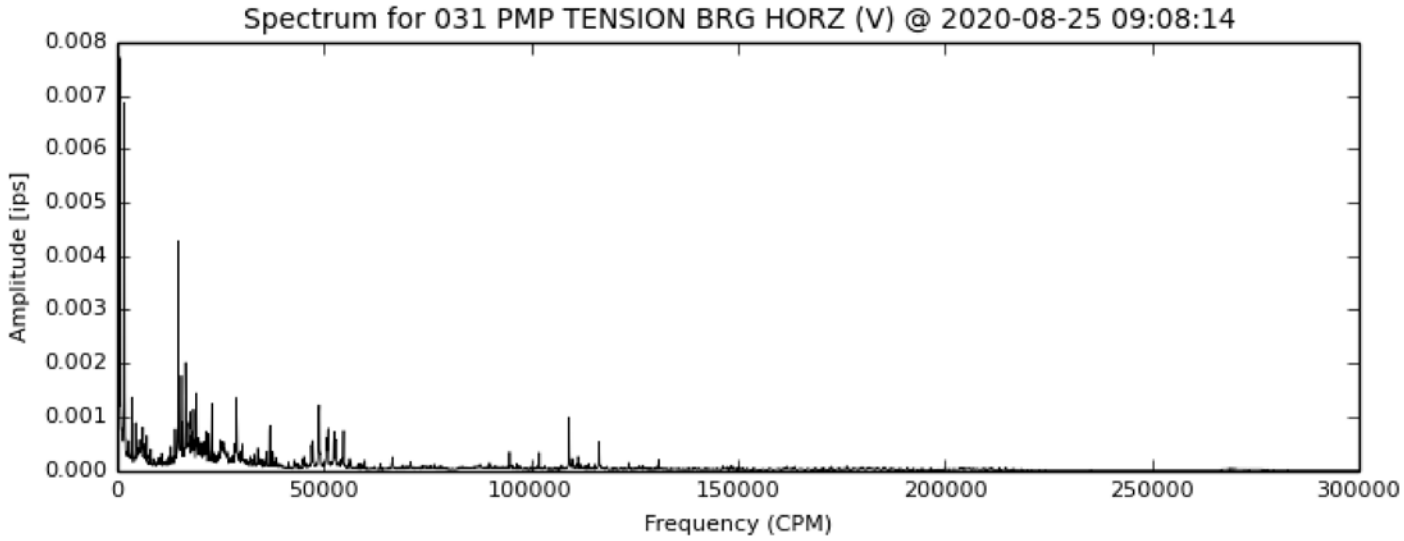
POINT: A21 LWR MTR BRG ACCEL (A)

Date	RMS	Severity
2020-08-25 09:05:34	0.4648 G's	GOOD



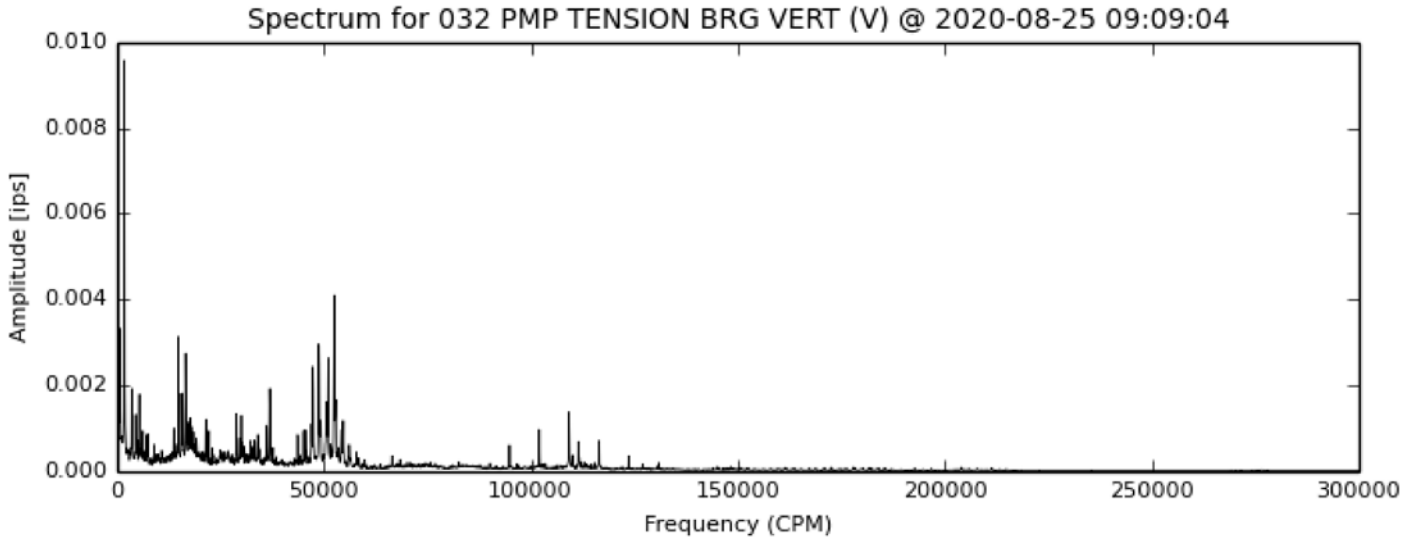
POINT: 031 PMP TENSION BRG HORZ (V)

Date	RMS	Severity
2020-08-25 09:08:14	0.0161 ips	GOOD



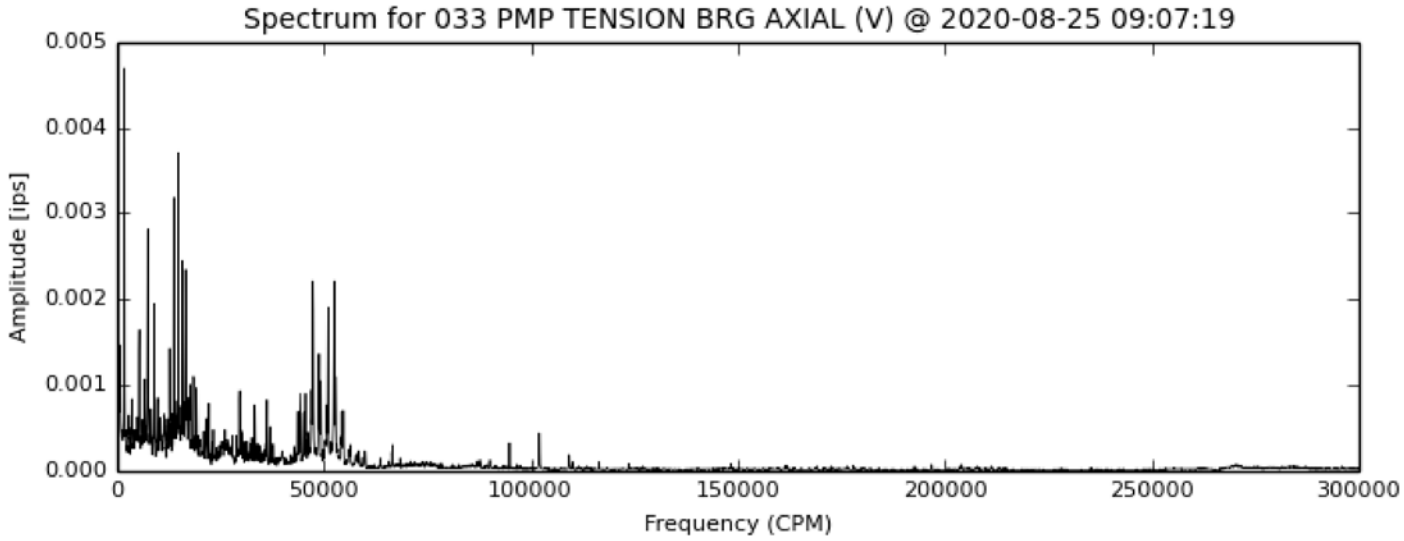
POINT: 032 PMP TENSION BRG VERT (V)

Date	RMS	Severity
2020-08-25 09:09:04	0.0202 ips	GOOD



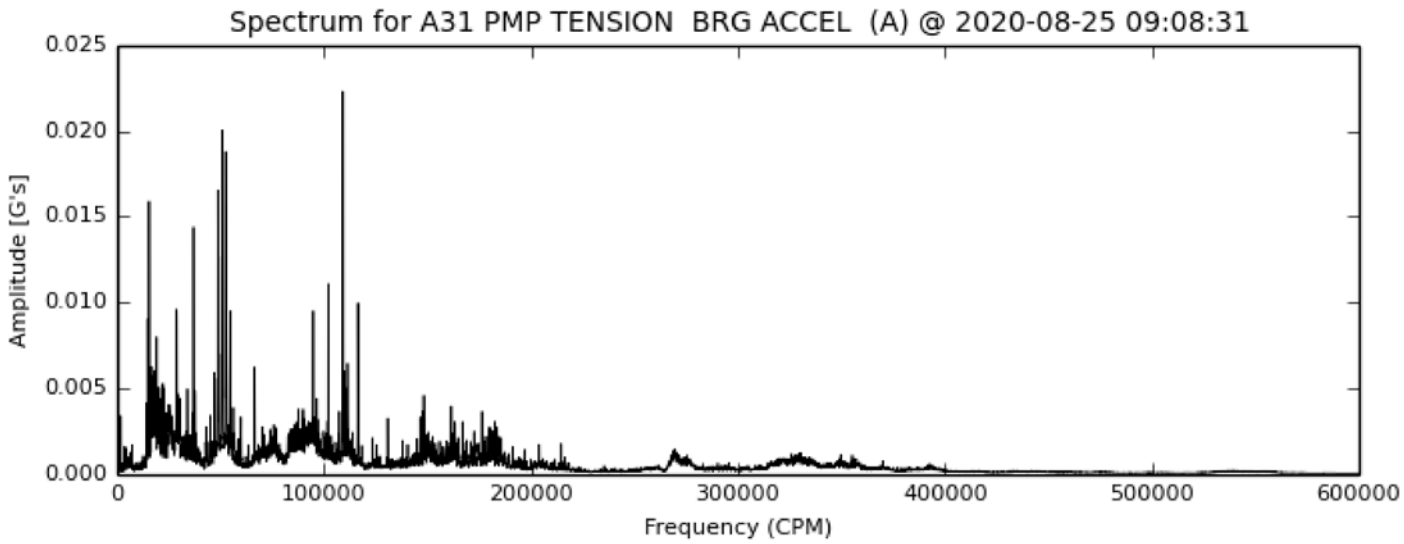
POINT: 033 PMP TENSION BRG AXIAL (V)

Date	RMS	Severity
2020-08-25 09:07:19	0.0152 ips	GOOD



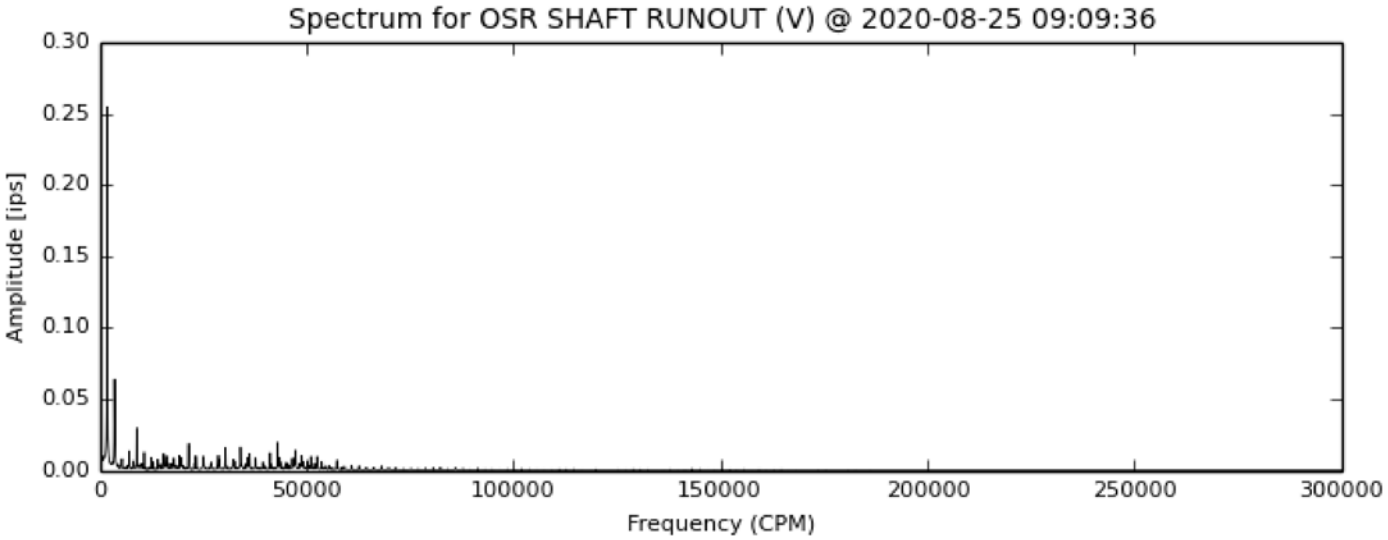
POINT: A31 PMP TENSION BRG ACCEL (A)

Date	RMS	Severity
2020-08-25 09:08:31	0.0997 G's	GOOD



POINT: OSR SHAFT RUNOUT (V)

Date	RMS	Severity
2020-08-25 09:09:36	0.2975 ips	GOOD


Spectrum for OSR SHAFT RUNOUT (V) @ 2020-08-25 09:09:36
Amplitude [ips]
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50000
100000
150000
200000
250000
300000
Frequency (CPM)

August 27, 2020

City of West University Place
Attn: Mr. Chad Smith
West University, Texas 77401

Reference: Water Well #9 – Wake Forest Dr.

Dear Mr. Smith,

Collection and evaluation of field data pertaining to the operation of the well and well pumping equipment was recently completed at the above referenced facility. Included in this report please find the test results and pump curve generated by the testing.

PERFORMANCE TEST REVIEW

Hydraulic Performance of pump is 1972 GPM @ 386' field head	Excellent __X__	Good ____	Marginal_____	Poor____
Overall efficiency is 68 percent	Excellent __X__	Good____	Satisfactory ____	Poor
Pump Submergence 238 feet	Excellent __X__	Good ____	Marginal____	Poor____
Vibration Analysis	Excellent _____	Good __X__	Marginal____	Poor____
Suspended Solids Testing	Excellent _____	Good__X__	Marginal____	Poor___
Brass Observed in SST	None _____X___	Trace_____	Substantial ___	Excessive__
Flowmeter Accuracy is 99.1 percent				

The test indicated that the pump appears to be operating in good condition.

We appreciate this opportunity to be of service. If you have any questions or comments, please call.

Sincerely,
Gary McMurrey

G-M SERVICES

SPECIALIZED INSPECTION SERVICES FOR THE WATER INDUSTRY

Performance Test Report

website: www.g-mservices.com phone: 281-894-8971

Facility City of West University Place - well #9 **Test Date** 08/25/2020

U.S.G.S. # LJ-65-xx-009 **Subsidence Well ID#:** 3986

PUMP DATA

Manufacturer :	Christensen
Bowl Type :	14" RJLC
Stages :	7
Setting :	580
Column Size :	10" x 3" x 1 15/16"
Design Point :	1600 GPM @ 522' TDH

MOTOR DATA

Manufacturer :	U.S. Motors
Size (HP) :	350
Amps/Volts :	389/460
Serial # :	X07 20160393-0001
Frame :	447TPA
Speed (RPM) :	1785

PERFORMANCE TEST DATA

Static Lvl (ft) -237

Discharge Pressure	19	42
Capacity (GPM)	1872	1763
Pumping Lvl (ft)	-342	-333
Drawdown (ft)	105	96
Specific Capacity	17.83	18.36
Field Head (ft)	385.89	430.02
Water Horsepower	182.4	191.64
Overall Efficiency	68%	71%
Horsepower Input	266.39	271.35
Kilowatt Input	198.8	202.5
Amp Draw	278-280-272	283-284-278
Voltage	487-488	487-489
Sand (PPM)	2	1
Time (min)	45	15

Meter Data

Manufacturer: Water Spec Size: 12

Serial #: 20200896

Meter Read: 025064.000

Meter accuracy is 99.1 % at 1855 GPM

Additional Data

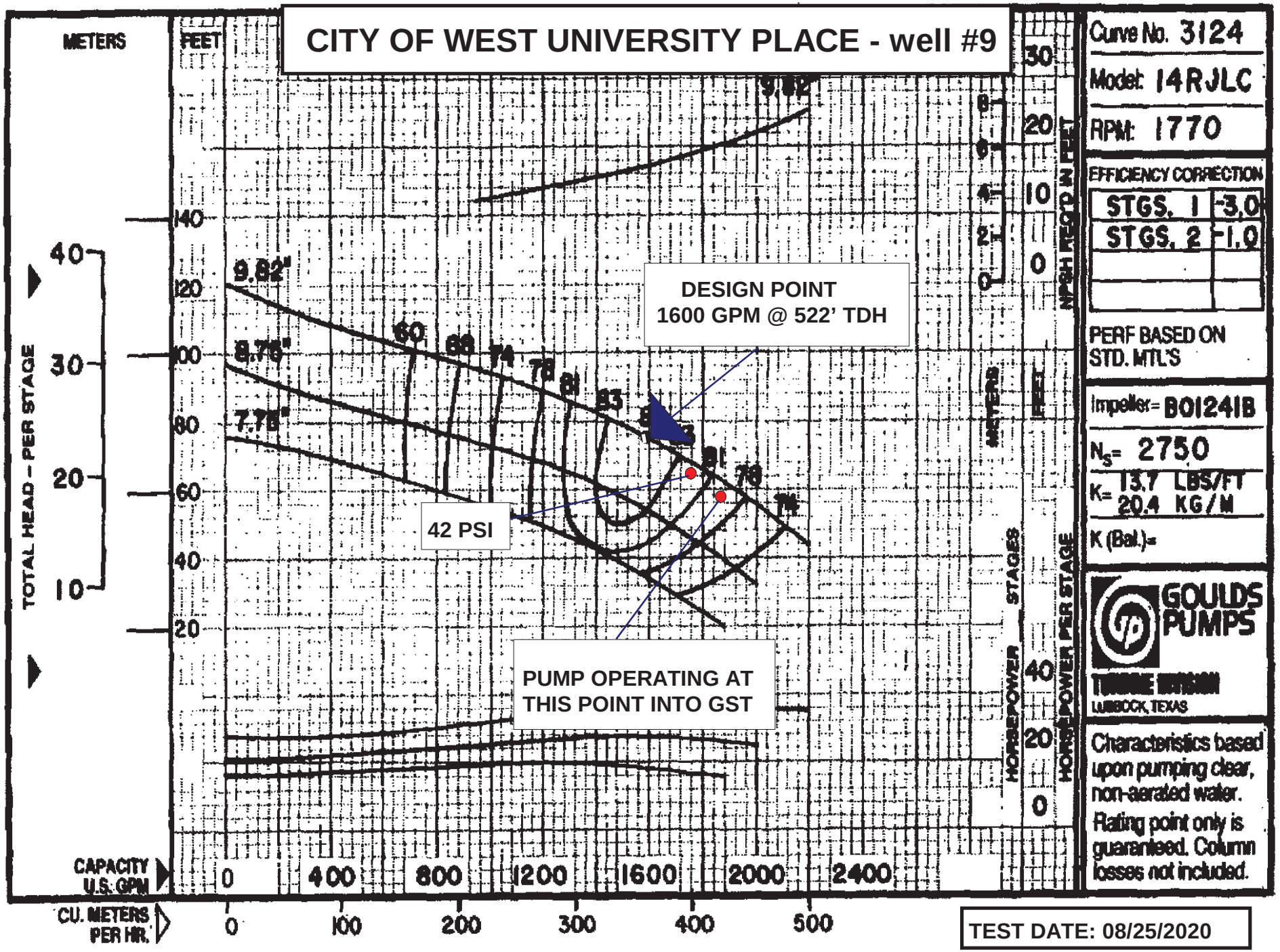
Start-up Sand (PPM)	5
Brass Detect:	No
Pump Submergence (ft)	238
ETM Read:	15534

Remarks

New meter installed.

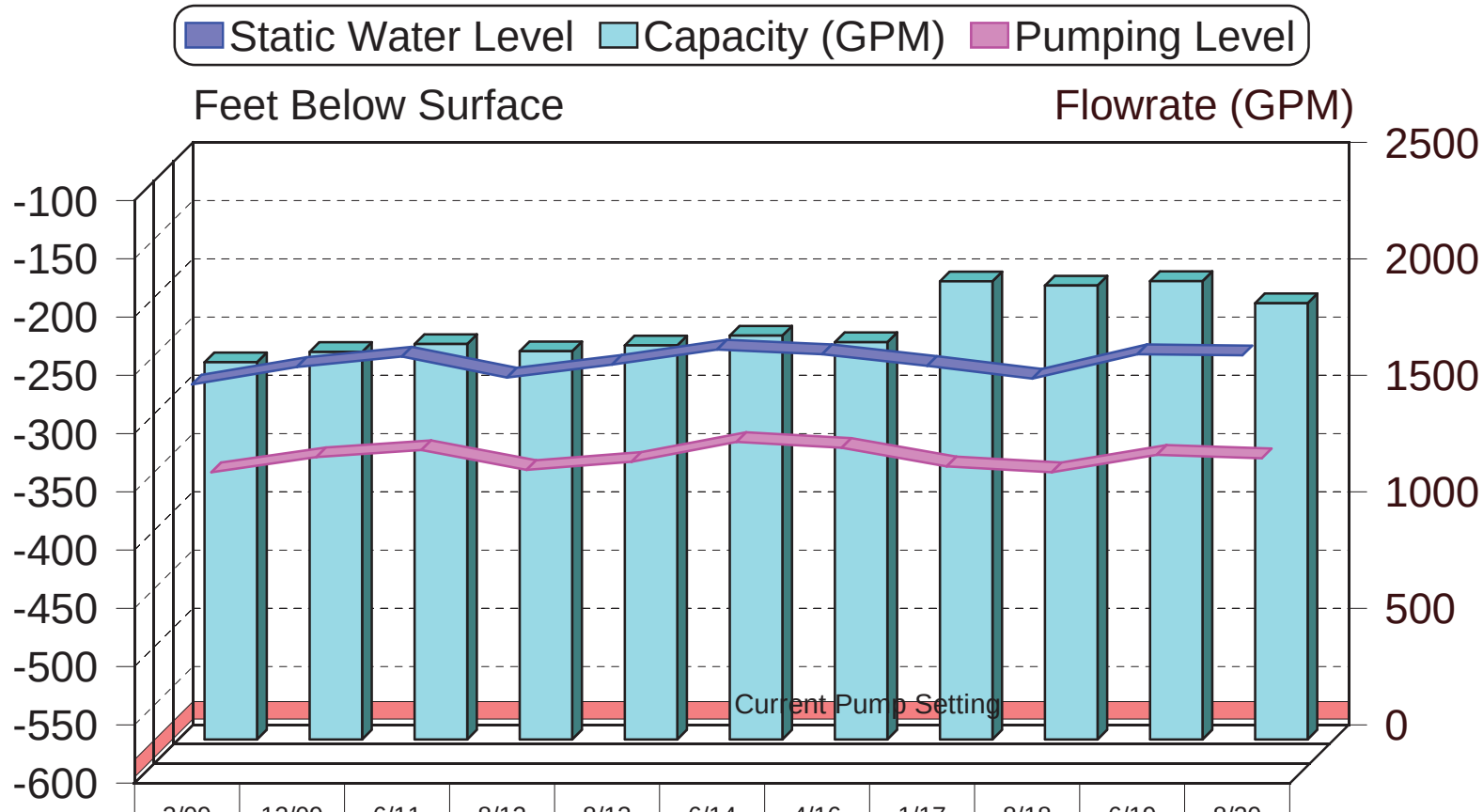
Vibration analysis completed.

TECHNICIAN R McKissick


CITY OF WEST UNIVERSITY PLACE - well #9
METERS
FEET
TOTAL HEAD – PER STAGE
CAPACITY U.S. GPM
CU. METERS PER HR.
0
400
800
1200
1600
2000
2400
100
200
300
400
500
9.82"
8.75"
7.75"
DESIGN POINT
1600 GPM @ 522' TDH
42 PSI
PUMP OPERATING AT
THIS POINT INTO GST
HORSEPOWER — STAGES
HORSEPOWER PER STAGE
NPSH REQD IN FEET
METERS
FEET
Curve No. 3124
Model: 14RJLC
RPM: 1770
EFFICIENCY CORRECTION
STGS. 1 -3.0
STGS. 2 -1.0
PERF BASED ON STD. MTL'S
Impeller= B01241B
N_s= 2750
K= 13.7 LBS/FT
20.4 KG/M
K (Bal.)=
GOULDS PUMPS
LUBBOCK, TEXAS
Characteristics based upon pumping clear, non-aerated water. Rating point only is guaranteed. Column losses not included.
TEST DATE: 08/25/2020

City of West University Place

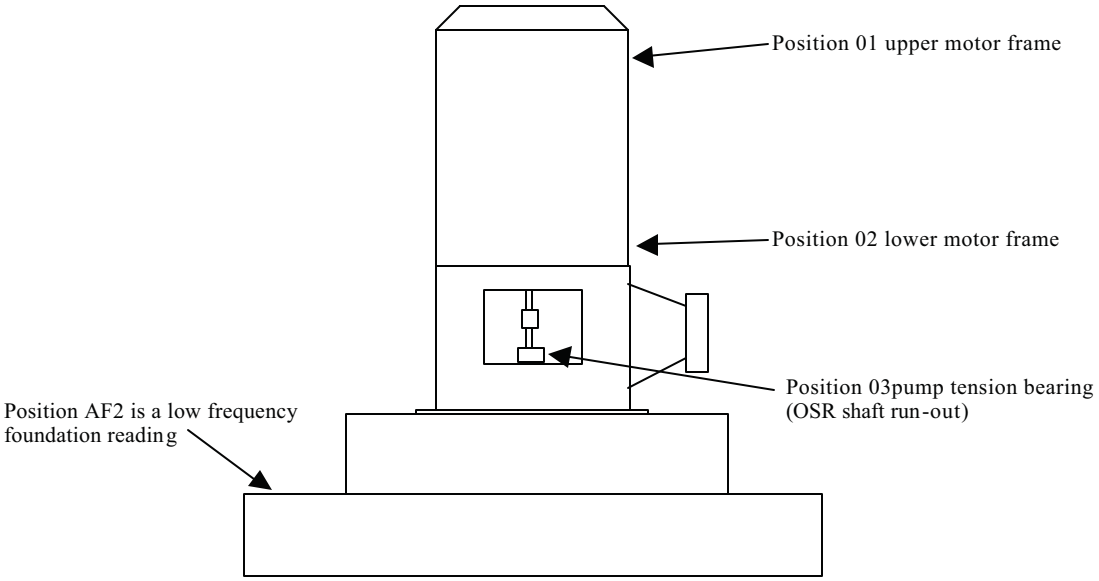
Well #9



	3/09	12/09	6/11	8/12	8/13	6/14	4/16	1/17	8/18	6/19	8/20
Static Water Level	-262	-247	-238	-256	-245	-232	-236	-246	-257	-236	-237
Capacity (GPM)	1619	1663	1697	1666	1691	1733	1705	1966	1948	1967	1872
Pumping Level	-354	-341	-335	-352	-345	-328	-333	-349	-354	-339	-342

Prepared by G-M Services

VIBRATION ANALYSIS DATA
TYPE 3 Machine



Explanation of vibration Identification System

First digit is measurement location	Second digit is direction
01 = upper motor bearing	1 = horizontal
02 = lower motor bearing	2 = vertical
03 = pump tension bearing	3 = axial

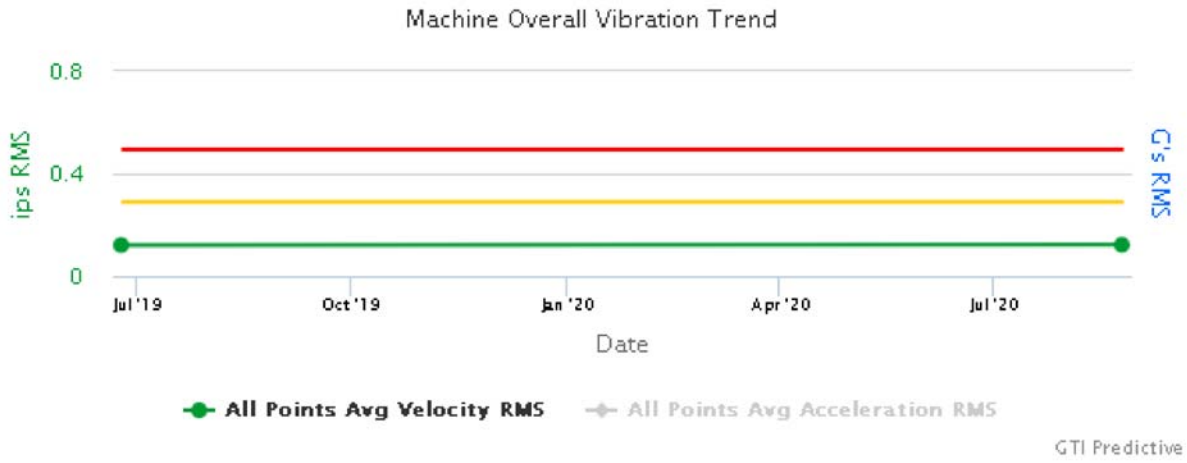
Example: Position 022 is the lower motor bearing vertical direction.
Position 031 is the pump tension bearing horizontal direction.

Measurement points are taken at each bearing. The points are numbered starting at the driver and ending at the driven end.

Note: Position AF2 is an acceleration reading on the pump foundation (axial position)
Position OSR is a shaft rider reading at the top of the tension bearing.

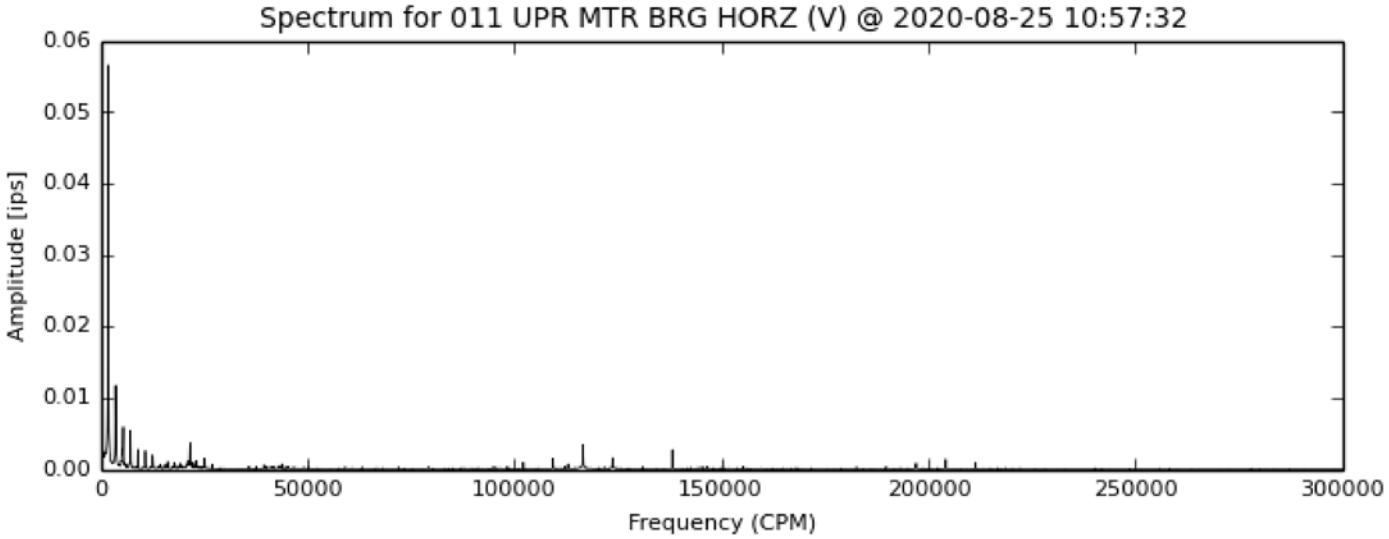
MACHINE REPORT
Report Date: Mon, Aug 31. 10:07:08 am EDT

Plant/Area: CITY OF
Machine name: WEST UNIVERSITY WW 9



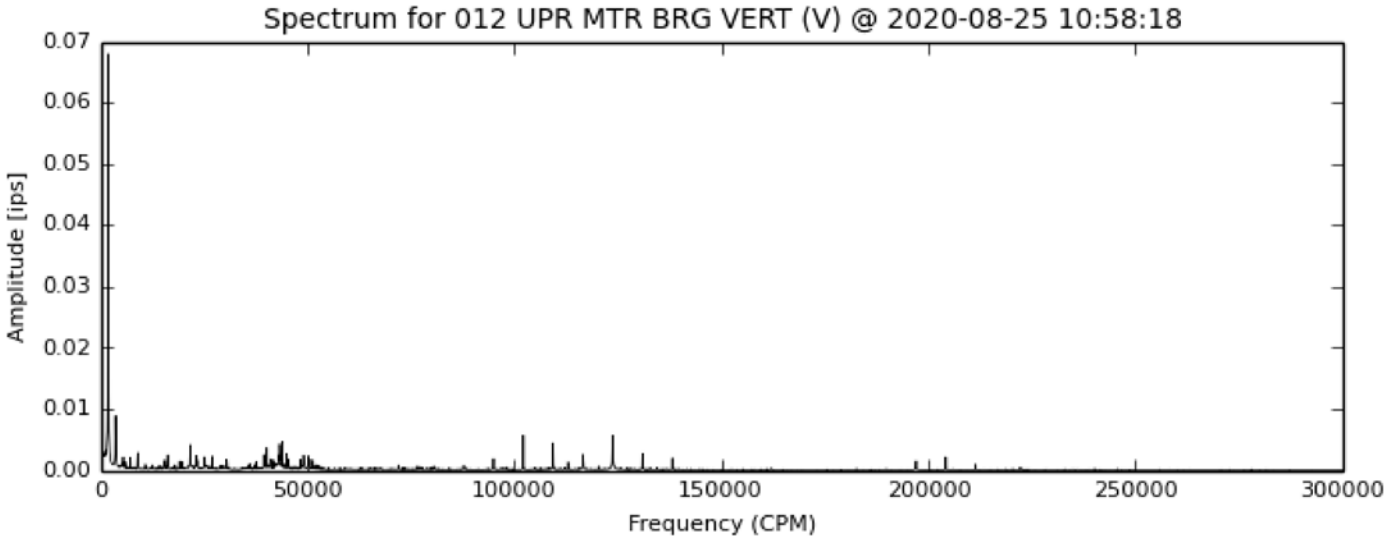
POINT: 011 UPR MTR BRG HORZ (V)

Date	RMS	Severity
2019-06-25 11:54:44	0.0586 ips	GOOD
2020-08-25 10:57:32	0.0651 ips	GOOD



POINT: 012 UPR MTR BRG VERT (V)

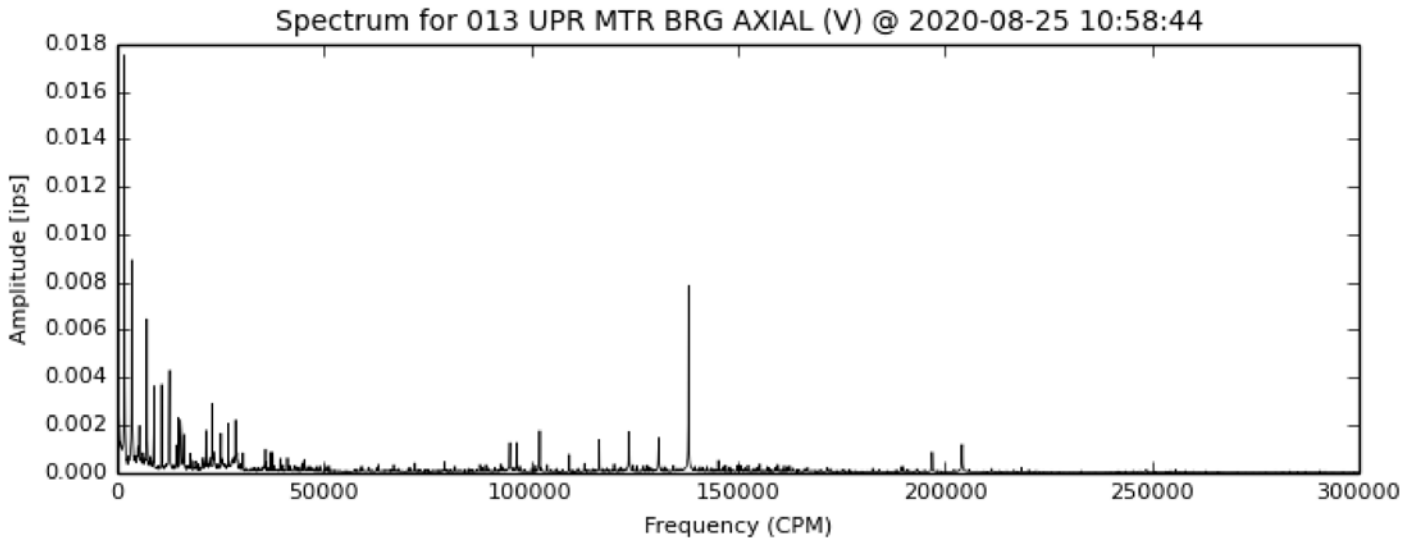
Date	RMS	Severity
2019-06-25 11:55:58	0.0671 ips	GOOD
2020-08-25 10:58:18	0.078 ips	GOOD



POINT: 013 UPR MTR BRG AXIAL (V)

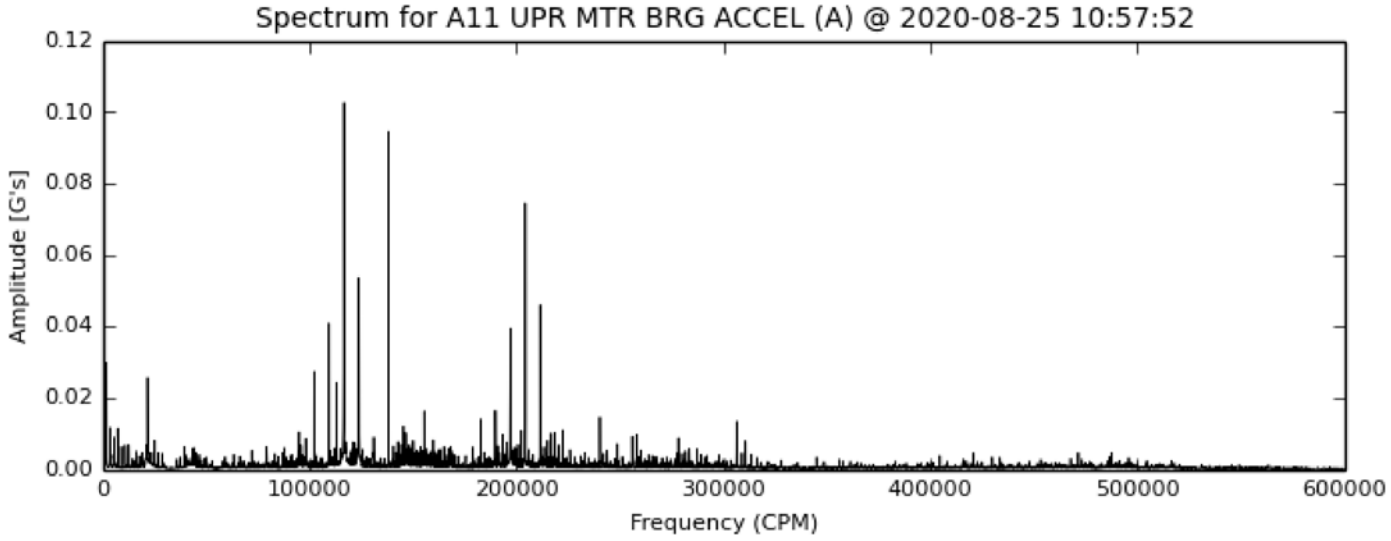
Date	RMS	Severity
2019-06-25 11:56:25	0.0299 ips	GOOD

2020-08-25 10:58:44	0.0297	ips	GOOD



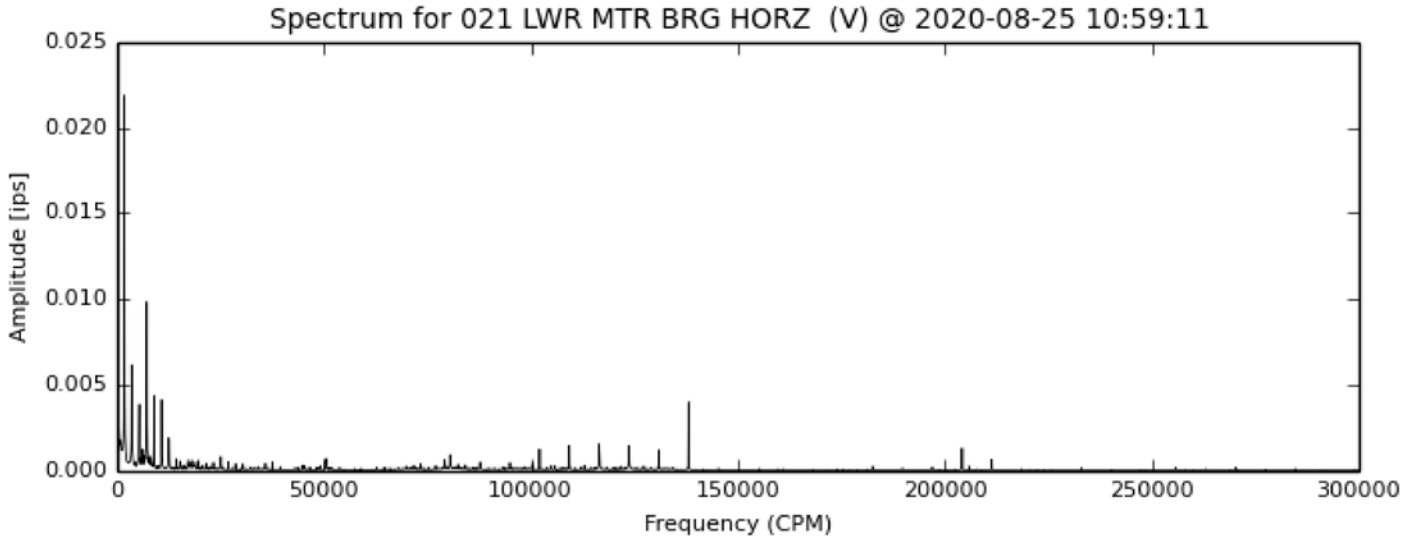
POINT: A11 UPR MTR BRG ACCEL (A)

Date	RMS		Severity
2019-06-25 11:55:13	0.2558	G's	GOOD
2020-08-25 10:57:52	0.2447	G's	GOOD



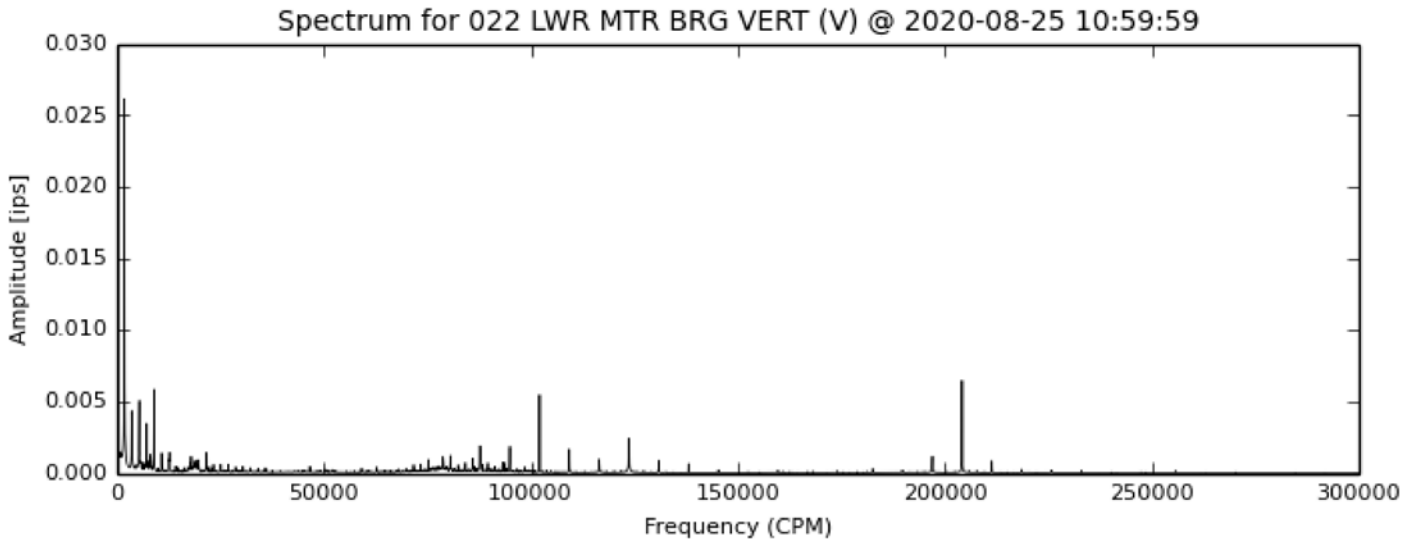
POINT: 021 LWR MTR BRG HORZ (V)

Date	RMS		Severity
2019-06-25 11:57:12	0.032	ips	GOOD
2020-08-25 10:59:11	0.0313	ips	GOOD



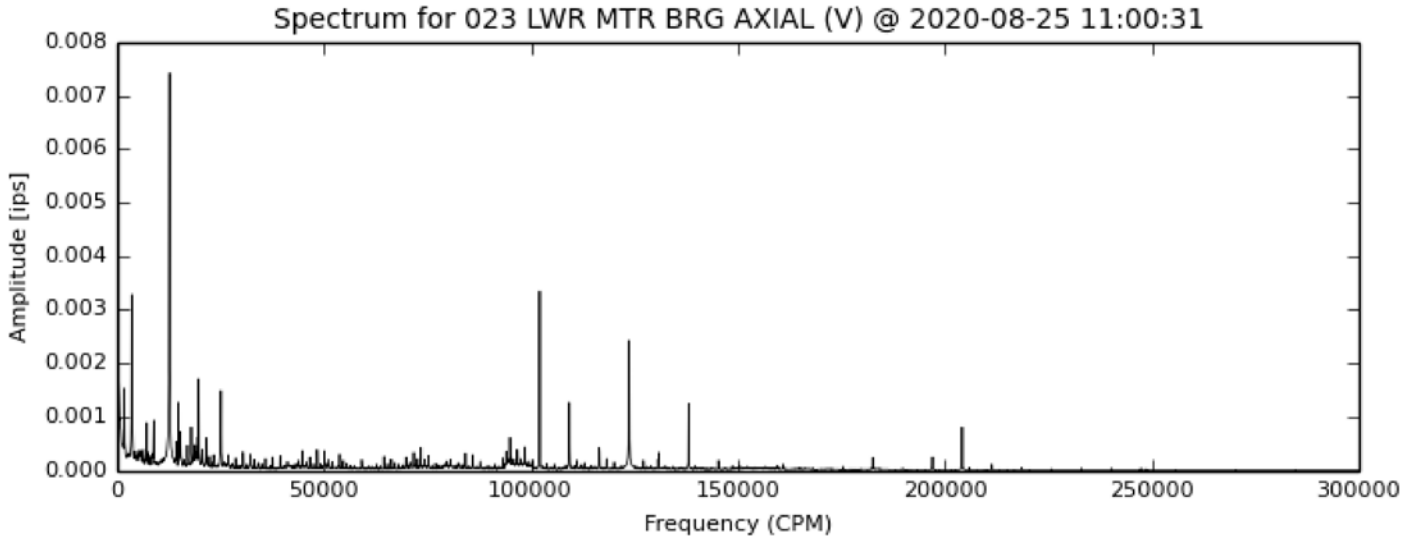
POINT: 022 LWR MTR BRG VERT (V)

Date	RMS	Severity
2019-06-25 11:58:31	0.0263 ips	GOOD
2020-08-25 10:59:59	0.0336 ips	GOOD



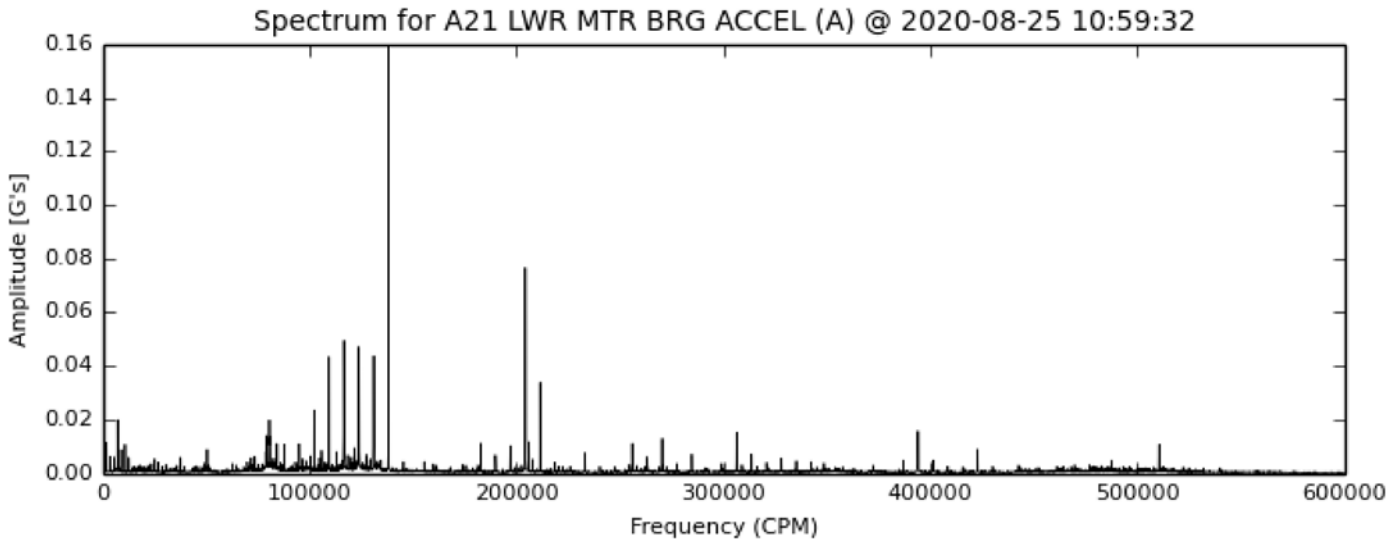
POINT: 023 LWR MTR BRG AXIAL (V)

Date	RMS	Severity
2019-06-25 11:59:07	0.0103 ips	GOOD
2020-08-25 11:00:31	0.0143 ips	GOOD



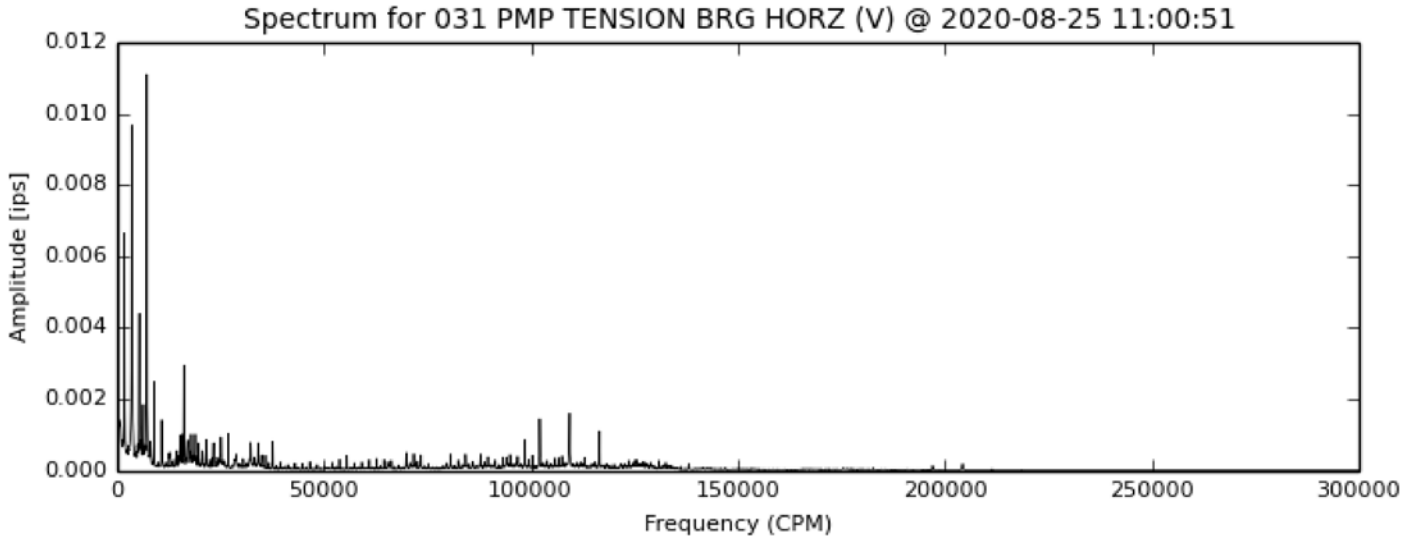
POINT: A21 LWR MTR BRG ACCEL (A)

Date	RMS	Severity
2019-06-25 11:57:44	0.1376 G's	GOOD
2020-08-25 10:59:32	0.2367 G's	GOOD



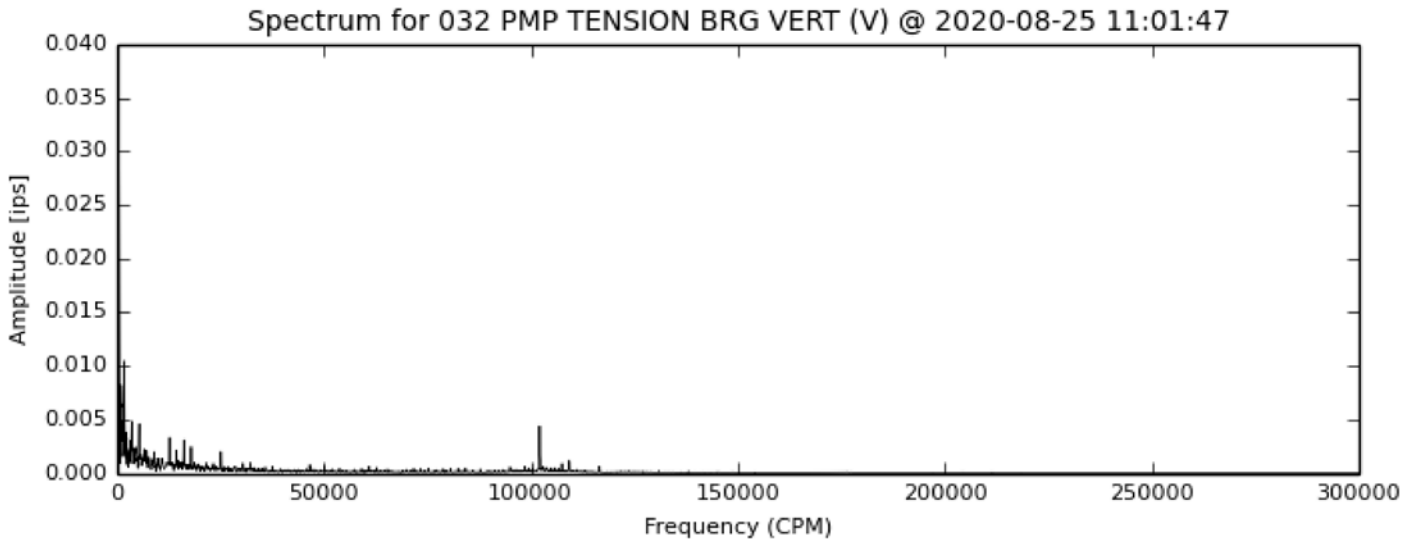
POINT: 031 PMP TENSION BRG HORZ (V)

Date	RMS	Severity
2019-06-25 11:59:34	0.0245 ips	GOOD
2020-08-25 11:00:51	0.0226 ips	GOOD



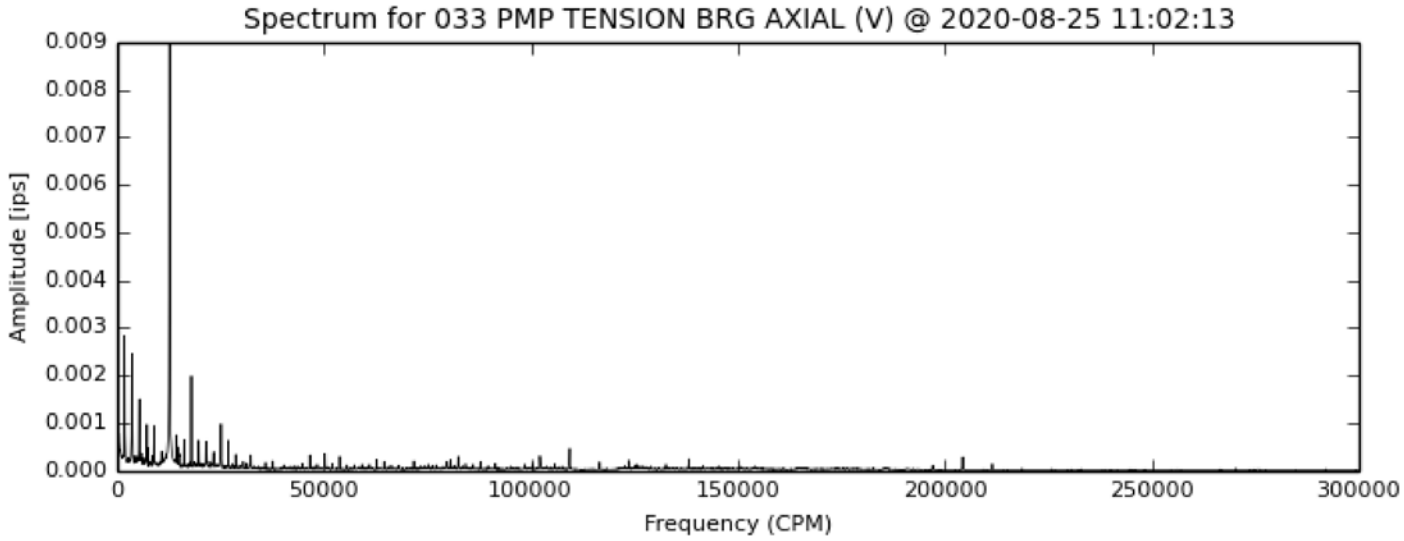
POINT: 032 PMP TENSION BRG VERT (V)

Date	RMS	Severity
2019-06-25 12:00:21	0.0196 ips	GOOD
2020-08-25 11:01:47	0.0772 ips	ALERT



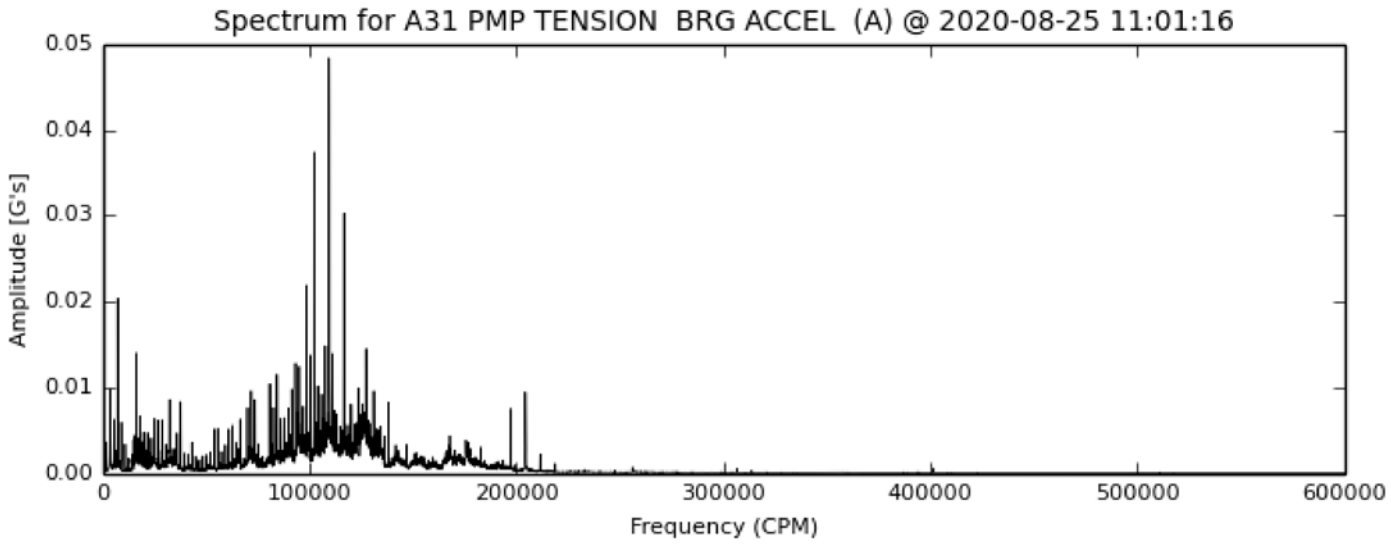
POINT: 033 PMP TENSION BRG AXIAL (V)

Date	RMS	Severity
2019-06-25 12:00:46	0.0083 ips	GOOD
2020-08-25 11:02:13	0.0127 ips	GOOD



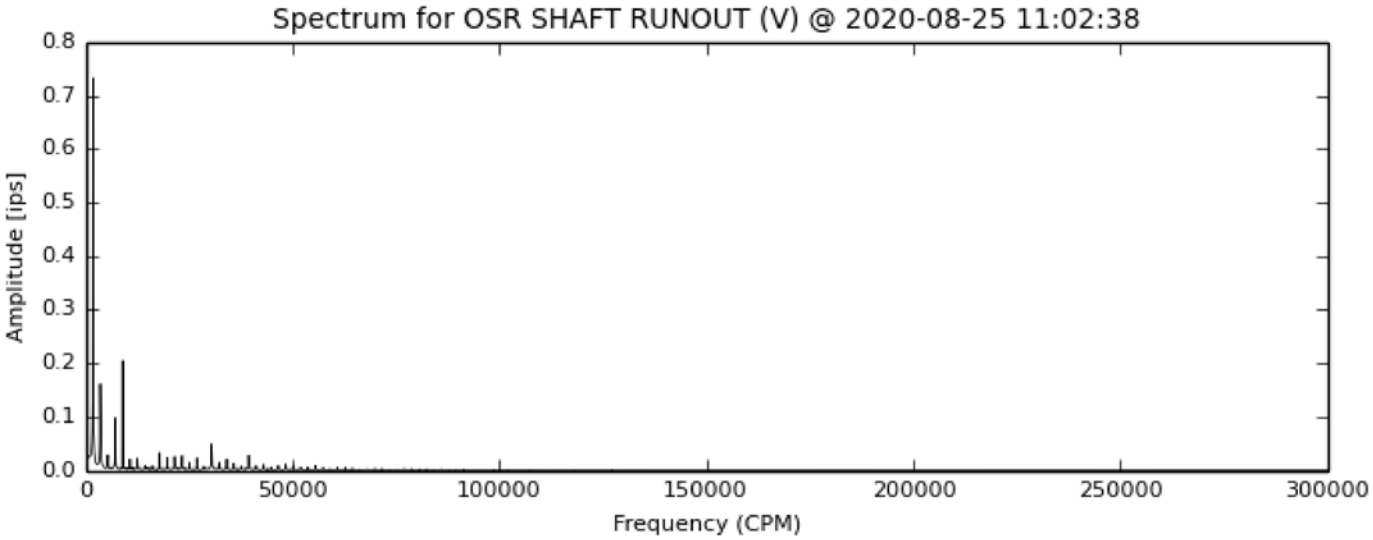
POINT: A31 PMP TENSION BRG ACCEL (A)

Date	RMS	Severity
2019-06-25 11:59:53	0.1902 G's	GOOD
2020-08-25 11:01:16	0.1519 G's	GOOD



POINT: OSR SHAFT RUNOUT (V)

Date	RMS	Severity
2019-06-25 12:01:06	0.9409 ips	GOOD
2020-08-25 11:02:38	0.8633 ips	GOOD


Spectrum for OSR SHAFT RUNOUT (V) @ 2020-08-25 11:02:38
Amplitude [ips]
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
50000
100000
150000
200000
250000
300000
Frequency (CPM)

APPENDIX B
Houston Surface Water Contract

WATER SUPPLY CONTRACT BETWEEN THE CITY OF HOUSTON, TEXAS AND THE CITY OF WEST UNIVERSITY PLACE, TEXAS

34086
94-99

THIS WATER SUPPLY CONTRACT ("Contract") is made by and between the **CITY OF HOUSTON, TEXAS,** ("Houston") and the **CITY OF WEST UNIVERSITY PLACE, TEXAS** ("West University").

RECITALS

Houston is a municipal corporation and home-rule city, principally located in Harris County, Texas. Houston owns a water distribution system and desires to sell surface water to West University.

West University is a home-rule municipal corporation organized under Texas law.

West University operates a water distribution system and desires to purchase water from Houston for distribution and use for domestic and commercial purposes.

The parties to this Contract have determined that all obligations to expend money arising out of this Contract can be fully satisfied out of moneys now on hand and available for expenditure for the purposes herein stated. In the case of periodic charges for water service, the parties contemplate that West University will pay such charges as an operating expense of its water system out of funds on hand at the time such charges are incurred.

NOW, THEREFORE, for and in consideration of the covenants and agreements herein contained, the parties hereto do mutually agree as follows:

ARTICLE I.

Definitions

Unless the context requires otherwise, the following terms as used in this Contract shall have meanings as follows:

"Ordinances" shall mean the Code of Ordinances of the City of Houston, Texas, as amended from time to time.

"Point of Delivery" is defined in Section 2.04.

"Project" means the construction of certain water facilities described in Section 2.02.

"Project Elements" or "Elements" are described in Section 2.02(a) and Exhibit "A".

"Utility Official" shall mean the Utility Official of the Department of Public Works and Engineering of the City of Houston, Texas, or any other person who may hereafter exercise the functions of the said Utility Official under the applicable Ordinances of City.

"Water" shall mean treated surface water from Houston's domestic waterworks system serving its own inhabitants.

ARTICLE II.

Construction of Facilities

2.01-- Construction by City.

Houston has constructed and is constructing sufficient water facilities to enable it to deliver Water to West University.

2.02--Construction by West University of Certain Facilities.

(a) West University and Houston have proposed the construction of a combined water facility Project to include the following five Elements:

(i) A 16-inch approach main along Weslayan Drive from Westpark to Bissonnet ("Weslayan Main").

(ii) Three fire hydrants along the Weslayan Main ("Weslayan Hydrants").

(iii) Various taps and connections off the Weslayan Main to serve Houston water facilities or customers in the Weslayan vicinity ("Weslayan Taps").

(iv) A tap and meter at the terminus of the Weslayan Main to serve West University, near the intersection of Weslayan and Bissonnet ("Bissonnet Tap & Meter").

(v) A 12-inch water main between the Bissonnet Tap & Meter and the West University's water plant on Milton Street ("Milton Connection").

These facilities are illustrated in Exhibit "A", attached. The Weslayan Main, the Weslayan Hydrants and the Weslayan Taps are within the corporate limits of Houston, and Houston proposes to take title to them and use them to serve not only West University but also customers of Houston. Accordingly, the parties have agreed to share costs as follows:

Project Elements	West University's Share	Houston's Share
Weslayan Main	50%	50%
Weslayan Hydrants	(Labor cost)	(Materials cost)
Weslayan Taps	0%	100%
Bissonnet Tap & Meter	100%	0%
Milton Connection	100%	0%

(b) West University has caused the plans and specifications for the Project to be developed by Langford Engineering, Inc. Both West University and Houston have approved the plans and specifications, and West University proposes to advertise for bids and award a single construction contract for the Project.

(c) Plans and specifications for the Project must require that the construction contractor carry insurance having the following coverages and limits as a minimum.

(1) Comprehensive General Liability Insurance on an occurrence basis including contractual liability, bodily injury, and completed operations.

Each occurrence	$ 600,000
Aggregate	$1,000,000

(2) Automobile Liability Insurance on an occurrence basis for owned and non-owned vehicles.

Each occurrence	$ 600,000

(3) Employer's Liability

Each Accident	$ 500,000

(4) Worker's Compensation Statutory

Each policy, except the Worker's Compensation insurance, must include Houston as an additional insured and provide for a waiver of subrogation in favor of Houston. The policies must provide that the insurer(s) give at least thirty (30) days notice to the Utility Official in the event of cancellation or material change in policy coverage. All policies required hereunder shall be written by companies having a certificate of authority to transact insurance business in the State of Texas.

Certificates of Insurance evidencing policies of insurance must be provided to the Utility Official for approval prior to commencement of construction of the Project.

Plans and specifications for the Project also must require that the construction contractor indemnify Houston for liability for bodily injury or death caused during construction of the Project. The language of the indemnity provision shall be as follows:

INDEMNIFICATION.

CONTRACTOR COVENANTS AND WARRANTS THAT IT WILL PROTECT, DEFEND, AND HOLD HARMLESS THE CITY OF HOUSTON, ITS EMPLOYEES, OFFICERS, AND LEGAL REPRESENTATIVES (COLLECTIVELY, THE "CITY") FROM ANY AND ALL THIRD PARTY CLAIMS, DEMANDS, AND LIABILITY, INCLUDING DEFENSE COSTS, RELATING IN ANY WAY TO DAMAGES, CLAIMS, OR FINES ARISING BY REASON OF OR IN CONNECTION WITH CONTRACTOR'S ACTUAL OR ALLEGED NEGLIGENCE OR OTHER ACTIONABLE

PERFORMANCE OR OMISSION OF THE CONTRACTOR IN CONNECTION WITH OR DURING THE PERFORMANCE OF THE DUTIES UNDER THIS AGREEMENT. ALSO, DURING THE PERFORMANCE OF THE WORK AND UP TO A PERIOD OF FIVE YEARS AFTER THE DATE OF FINAL ACCEPTANCE OF THE WORK, CONTRACTOR FURTHER EXPRESSLY COVENANTS AND AGREES TO PROTECT, DEFEND, INDEMNIFY, AND HOLD HARMLESS THE CITY FROM ALL CLAIMS, ALLEGATIONS, FINES, DEMANDS, AND DAMAGES RELATING IN ANY WAY TO THE ACTUAL OR ALLEGED JOINT AND/OR CONCURRENT NEGLIGENCE OF THE CITY AND CONTRACTOR, WHETHER CONTRACTOR IS IMMUNE FROM LIABILITY OR NOT.

IT IS THE EXPRESSED INTENTION OF THE PARTIES HERETO THAT THE INDEMNITY PROVIDED HEREIN IS AN AGREEMENT BY THE CONTRACTOR TO INDEMNIFY AND PROTECT THE CITY FROM THE CITY'S OWN NEGLIGENCE WHERE SAID NEGLIGENCE IS AN ALLEGED OR ACTUAL CONCURRING PROXIMATE CAUSE OF ANY ALLEGED THIRD-PARTY HARM.

THE INDEMNITY PROVISION PROVIDED HEREIN SHALL HAVE NO APPLICATION TO ANY CLAIM OR DEMAND WHERE BODILY

INJURY, DEATH, OR DAMAGE RESULTS ONLY FROM THE SOLE NEGLIGENCE OF THE CITY UNMIXED WITH ANY FAULT OF THE CONTRACTOR.

NOTWITHSTANDING ANYTHING HEREIN TO THE CONTRARY, THE LIABILITY OF THE CONTRACTOR UNDER THIS INDEMNITY PROVISION SHALL NOT EXCEED $1,000,000 PER OCCURRENCE.

(d) West University and Houston agree that each party will bear the above-indicated shares of the costs of each element of the Project. The costs to be borne include the actual and reasonable costs for surveys, engineering, testing, construction contract payments, construction management and inspection, advertisements, and legal services reasonably necessary for the Project, which services are provided by an independent contractor for West University (the total cost for each Element is initially estimated at 115% of the estimated construction payments). Any cost item incurred solely for one element of the Project shall be allocated solely to that Element. Cost items incurred for two or more Elements in common (overall engineering, for example) shall be allocated to those Elements pro rata, in proportion to the construction contract prices for those Elements. The current estimates of cost, by Project Element, are as follows:

Project Elements	West University's Share*	Houston's Share*
Weslayan Main	$154,457	$154,457
Weslayan Hydrants	$ 6,900	$ 3,450
Weslayan Taps	$ 0	$ 5,635

Bissonnet Tap & Meter	$ 23,000	$ 0
Milton Connection	$276,028	$ 0
TOTALS	$460,385	$163,542

*These figures for each Element are initially estimated at 115% of the estimated construction payments.

(e) The parties have agreed that the cost quotes on the bid form shall be arranged so that prices for the five Project Elements can be determined from the face of the bid. The proposed bid form is part of the plans and specifications prepared by Langford Engineering and has been approved by both West University and Houston.

After bids have been opened, the parties shall calculate Project costs, and West University shall send a statement of costs to the Utility Official. The statement of Project costs shall include a complete itemization of all costs described in subsection (d), broken down by Project Elements. Upon approval by the Utility Official, whose approval shall not be unreasonably denied or withheld, Houston shall pay Houston's estimated share of the estimated Project cost described in West University's statement, plus 5% thereof for contingencies. Payment by Houston shall be made within thirty (30) days of its receipt of West University's statement of costs.

(f) When West University has the full estimated cost of the Project on hand, it shall proceed with the award of a construction contract to the lowest responsible bidder. During the course of the work, Houston agrees to assist West University, providing timely engineering reviews, inspections, permit decisions, etc., as required hereunder. Houston agrees to waive

any permit fees and provide expedited handling, if reasonably necessary. West University shall obtain prior written approval of the Utility Official for any change order in excess of $5,000.

(g) Upon completion of the Project, West University shall prepare and deliver to the Utility Official plans showing the Project facilities as constructed. West University shall assign to Houston all construction contractor warranties as well as West University's rights under the performance bond submitted by the construction contractor. (This subsection only applies to the Weslayan Main, the Weslayan Hydrants, the Weslayan Taps and the Bissonnet Tap & Meter.)

(h) When all costs of the Project are known within a reasonable certainty but no later than six (6) months after substantial completion of the Project, West University shall make a calculation of the actual costs incurred by West University for the Project and for the five Elements included in the Project, and a copy of the calculation shall be provided to the City. A "true up" payment shall be made between the parties so that the payments by Houston match Houston's agreed-upon share of the actual costs. This may require either a refund by West University or an additional payment by Houston. If at the six-month deadline there is an unresolved claim or dispute that affects the final Project cost, the deadline shall be extended fro day to day until the claim or dispute is resolved.

(i) After the "true up" payment is made, West University shall convey title to the Weslayan Main, the Weslayan Hydrants and the Weslayan Taps to Houston by Bill of Sale in substantially the form shown in Exhibit "C" attached. Provided, West University shall have a right to 50% of the conveyance capacity of the Weslayan Main under normal operating

conditions. Houston shall be responsible for operating, maintaining, repairing and replacing the facilities conveyed to it.

(j) When the Project is completed, West University shall determine when its system is ready to receive initial deliveries of Water under this Contract and shall so notify Houston of the date for commencement of delivery of Water. At such time, sale and delivery of water shall begin under Article III of this Contract.

(k) West University's Treasurer shall hold all sums deposited by Houston under this Section, in an interest-bearing account and secured in the manner required by law for public funds, until they are used as provided in this Contract. Such deposited sums shall only be used to pay for Houston's agreed-upon share of the costs of the Project. Because West University will have already paid both its own share and Houston's share of "up-front" costs like engineering, part of the sums deposited by Houston may be used to pay Houston's share of the "up-front" costs by reimbursing the fund from which the "up-front" costs were paid. West University shall keep accurate records of all earnings and expenditures of such account and shall provide Houston a detailed report on all account activity at least once a year until completion of the Project, at which time West University shall turn over to Houston all copies of records of the account.

(l) West University recognizes that Houston has only appropriated the sum of $172,000 to pay for its share of the costs for the Project. Houston is only obligated to make payments out of said appropriation, but in case of Project overruns Houston's City Council may

make additional appropriations. If Houston does not make a full payment otherwise required by this Contract, but which would be in excess of Houston's original appropriation, West University may terminate this without fault Contract by so notifying Houston, or proceed with construction of the Project and offset the unpaid amounts against any amounts West University may owe Houston.

2.03--Time of Completion.

West University and Houston agree to proceed with due diligence to construct the facilities described in Section 2.01, 2.02 and 2.05 as appropriate.

2.04--Point(s) of Delivery.

The Points of Delivery for Water sold under this Contract shall be located at the outlet flamage of each meter described in Exhibit "B", which is attached hereto and incorporated by reference. A reference in this Contract to a Point of Delivery or meter shall be construed as referring to each of the two Points of Delivery and meters described in Exhibit "B". The readings of the two meters shall be combined for purposes of billing and payment.

2.05--Tap and Meter.

West University shall construct, at its sole cost, a tap and set the water meter for the Bissonnet connection under the approval and inspection of the Utility Official. The water meter shall be located at the Bissonnet Point of Delivery. West University's water distribution system shall be chlorinated before the connection is made.

ARTICLE III.

Sale and Delivery of Water

3.01--Delivery of Water.

Subject to the terms and conditions of this Contract, Houston agrees to sell and deliver (or cause to be delivered) Water at the Points of Delivery established under the provisions of Article Two, and West University agrees to purchase Water at such Points of Delivery during the term of this Contract.

3.02--Billing and Payment.

All Water delivered to the West University shall be metered, and Houston shall read the meters and bill West University on a monthly basis. The charge for Water shall be computed in accordance with the rates for contract treated water customers (surface water) established by Section 47-61 of the Ordinances. Billing shall not begin until the commencement of delivery of Water.

Monthly payments shall be calculated in accordance with the formula given in subsection 47-61(f) of the Ordinances for contract treated water customers receiving only surface water. West University's initial minimum monthly quantity is 43,790,000 gallons. West University is authorized to revise its minimum monthly quantity no more than once each calendar year by providing notice thereof to the Utility Official. At the end of each billing period, Houston shall send a statement of charges to West University showing the quantity of Water measured by meter and the appropriate monthly charges.

During any monthly period in which Houston is unable to deliver to West University the minimum specified, whether as a result of temporary curtailments under Section 5.03 or of a force majeure as provided in Sections 5.01 and 5.02 hereof, West University shall be obligated to pay Houston only for the quantity of Water delivered to West University under this Contract during such month.

Payment of such statements shall be due and payable at P.O. Box 1562, Houston, Harris County, Texas 77251, on or before the 30th day after receipt of such statement. If Houston changes the location at which payment is to be made, Houston shall notify West University in writing at the address shown in Section 7.07 hereof.

Although Houston intends that contracts for the sale of Water for out-of-city usage for domestic and commercial purposes should provide stable prices, it is recognized that Houston retains the right to change rates or increase rates to all customers by amending or superseding the rates set out in Section 47-61 of the Ordinances. It is agreed, however, that such rates shall not be increased as to West University during the term of this Contract unless such increase is also made applicable to other similar customers taking treated surface water from Houston. West University agrees to assess user charges to its customers that will produce revenues sufficient to discharge its obligations under this Contract.

3.03--Failure to Pay when Due.

Should West University fail to tender payment of any amount when due, interest thereon shall accrue at the rate of ten percent (10%) per annum from the date when due until paid. In

the event West University fails to timely tender payment of any amount within the 30-day period established in Section 3.02 hereof, and such failure continues for 30 days after the Utility Official's written notice West University of such default, the Utility Official may suspend delivery of Water, but the exercise of such right shall be in addition to any other remedy available to Houston.

3.04--Title to and Responsibility for Water.

Title to, possession, and control of Water shall remain in Houston until it passes through the Point of Delivery, where title to, possession, and control of the Water shall pass from Houston to West University.

ARTICLE IV.

Term

This Contract shall be in force and effect from and after the countersignature hereof by Houston's Controller and shall expire at noon on the 40th anniversary of the date of countersignature unless sooner terminated pursuant to the terms of this Contract.

ARTICLE V.

Performance by the Parties

5.01--Force Majeure.

In the event either party is rendered unable, wholly or in part, by Force Majeure, to carry out any of its obligations under this Contract, it is agreed that upon such party's giving notice and full particulars of such Force Majeure in writing to the other party as soon as possible

after the occurrence of the Force Majeure, the obligations of the party giving such notice, to the extent it is affected by Force Majeure and to the extent that due diligence is being used to resume performance, shall be suspended for the duration of the Force Majeure. Such cause shall, as far as possible, be remedied with all reasonable dispatch.

5.02--Force Majeure Defined.

The term "Force Majeure", as used herein, shall include, but not be limited to, acts of God, strikes, lockouts or other industrial disturbances, acts of the public enemy, war, blockades, insurrections, riots, epidemics, landslides, lightning, earthquakes, fires, storms, floods, washouts, droughts, tornadoes, hurricanes, arrests and restraints of government and people, explosions, breakage or damage to machinery, pipelines or canals, and any other inabilities of either party, whether similar to those enumerated or otherwise, and not within the control of the party claiming such inability, which by the exercise of due diligence and care such party could not have avoided.

5.03--Delivery Limitations; Suspension of Services.

West University shall not be guaranteed any specific quantity or pressure of Water whenever Houston's water supply is limited or when Houston's equipment may become inoperative due to unforeseen breakdown or scheduled maintenance and repairs.

If the Houston City Council finds that public health, safety and welfare of Houston requires suspension in whole or part of the delivery of Water under this Contract, such suspension will be effective upon such determination made by the Houston City Council and will

continue until such time as determined by the Houston City Council. Provided, however, Houston may reduce the supply of Water only in accordance with the laws of the State of Texas, particularly Section 11.039(a) of the Texas Water Code. Houston agrees that delivery of Water to West University shall not be adversely affected by any alleged "prior vested right" under Section 11.039(b) of the Texas Water Code asserted by any treated water customer, raw water industrial customer or raw water municipal customer based on Houston's sale of water to such customer.

Houston is in no case to be held to any liability for failure to furnish any specific amount or pressure of Water. West University agrees to restrict its peak usage to no more than 1,500 gallons of Water per minute through the Bissonnet Point of Delivery unless a higher rate is authorized by the Utility Official. Rates of usage under this paragraph are computed by dividing the total usage on any given day by the number of minutes in the day (1,440). The total usage is determined by the regular measuring equipment at the Bissonnet Point of Delivery.

ARTICLE VI.

Measuring Equipment

6.01--In General.

At West University's own cost and expense, West University shall provide, for installation at the Point of Delivery located on Bissonnet Street, measuring equipment, properly equipped with meters and devices of standard type for measuring accurately the quantity of Water delivered under this Contract, with a capacity to measure the quantity of Water delivered

within the accuracy tolerance of 2%. Such measuring equipment shall be approved by West University and the Utility Official, but shall become the property of Houston after installation. (The existing measuring equipment installed at the Wakeforest Point of Delivery is approved by both parties.)

6.02--Access.

During any reasonable hours, Houston and West University shall have access to such measuring equipment so installed. West University shall have access to all records pertinent to determining the measurement and quantity of Water actually delivered, but the reading of the meters for purposes of billing shall be done by Houston.

6.03--Routine Tests.

Houston shall maintain the measuring equipment so installed within the accuracy tolerance of 2% by periodic tests conducted at least once every twelve (12) months and shall notify West University at least forty-eight (48) hours in advance of the time and location at which tests are to be made. Houston agrees to properly test said measuring equipment when requested to do so by West University. In addition, West University shall have the right to independently check said measuring equipment at any time upon notification to the Utility Official.

6.04--Results of Tests.

Should the test of the meter in question show that the meter registers either more than one hundred two percent (102%) or less than ninety-five percent (95%) of the Water delivered

at the American Water Works Association (AWWA) specified test flow rates for that size and type meter, the water bills of West University shall be corrected to the average daily consumption of the meter when in working order and the meter shall be calibrated to AWWA specifications or replaced by an accurate meter that is tested before it is placed in service. This adjustment shall be for a period extending back to the time when the inaccuracy began, if such time is ascertainable; and if such time is not ascertainable, for a period extending back to the last meter test or one hundred twenty (120) days, whichever is shorter.

6.05--Disputes as to Testing.

In the event of dispute between Houston and West University as to the accuracy of the testing equipment used by the Houston to conduct the test of accuracy upon the meter being used, an independent check shall be mutually agreed upon between West University and Houston to be conducted by an independent measuring equipment company suitable to both West University and the Utility Official. The cost of such test will be at West University's sole expense.

ARTICLE VII.

Miscellaneous Provisions

7.01--Quality of Water.

Houston shall provide treated surface Water meeting all applicable Texas and Federal regulations regarding water quality, including the Safe Drinking Water Act.

EXCEPT AS PROVIDED IN THIS SECTION 7.01, HOUSTON MAKES NO WARRANTY EXPRESSED OR IMPLIED, REGARDING THE QUALITY OR DELIVERY PRESSURE OF THE WATER, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

WEST UNIVERSITY HEREBY RELEASES AND DISCHARGES HOUSTON FROM ANY AND ALL FINES, DEMANDS, JUDGEMENTS, LIABILITIES OR CLAIMS ARISING BY REASON OF OR IN CONNECTION WITH THE DELIVERY OF WATER WHICH MEETS THE REQUIREMENTS OF THIS SECTION 7.01.

7.02--Water Conservation Program

On or before February 1, 1995 West University shall approve and implement a water conservation program as required by the Texas Natural Resource Conservation Commission, pursuant to 31 T.A.C. §288.

7.03--Ingress and Egress.

During the terms of this Contract, West University and Houston shall have the right of ingress and egress in, upon under and over any and all land, easements and rights-of-way of West University and Houston on which West University or Houston, with the other's consent, constructs facilities to deliver Water to West University.

7.04--Assignments.

This Contract shall bind and benefit the respective parties and their legal successors, but shall not otherwise be assignable at law or otherwise, in whole or in part, by either party without first obtaining written consent of the other.

7.05--Subject to Law, etc..

This Contract shall be subject to all present and futures valid laws, orders, rules and regulations of the United States of America, the State of Texas, any regulatory body having jurisdiction, and the Charter and Ordinances of the City of Houston, Texas.

7.06--No Additional Waiver Implied.

The failure of either party hereto to insist, in any or more instances upon performance of any of the terms, covenants or conditions of this Contract, shall not be construed as a waiver or relinquishment of the future performance of any such term, covenant or condition by the other party hereto, but the obligation of such other party with respect to such future performance shall continue in full force and effect.

7.07--Inspections.

West University agrees that Houston may conduct inspections from time to time to determine that no conditions exist in West University's water distribution system and connections to its customers' premises which would or might adversely affect Houston's Water distribution system. In order to protect Houston's Water distribution system it is specifically agreed that West University's water distribution system shall be constructed and operated to comply with

Natural Resources Conservation

and with the City of Houston Plumbing Code,

the rules promulgated by the Texas Water Commission regarding backflow prevention, and cross connections. Should such a condition be discovered, West University shall promptly cure same.

any necessary air gaps,

Provided, however, the requirements of this section shall not apply if West University has installed backflow prevention systems satisfactory to the Utility Official at both Points of Delivery.

7.08--Merger.

This instrument contains all the agreements made between the parties.

7.09--Notices.

Until West University is otherwise notified in writing by Houston, the address of Houston is and shall remain as follows:

City of Houston
Director of Public Works and Engineering
P.O. Box 1562
Houston, Texas 77251

Until Houston is otherwise notified in writing by West University, the address of West University is and shall remain as follows:

City of West University Place
Attn: City Manager
3800 University Blvd.
Houston, Texas 77005

All written notices, statements and payments required or permitted to be given under this Contract from one party to the other shall be deemed given by the deposit in a United States Postal Service mailbox or receptacle of certified or registered mail, with proper postage affixed

thereto, addressed to the respective other party at the address set forth above or at such other address as the parties respectively shall designate by written notice.

7.10--Authorship.

The parties agree that this Contract shall not be construed in favor of or against either party on the basis that the party did or did not author this Contract.

7.11--Parties in Interest.

This Contract shall be for the sole and exclusive benefit of the parties hereto and shall not be construed to confer any rights upon any third party. Houston shall never be subject to any liability in damages to any customer of West University for any failure to perform under this Contract.

7.12--Captions.

The captions appearing at the first of each numbered section in this Contract are inserted and included solely for convenience and shall never be considered or given any effect in construing this Contract, or any provisions hereof, or in connection with the duties, obligations, or liabilities of the respective parties hereto or in ascertaining intent, if any questions of intent should arise.

7.13--Approvals.

Unless otherwise provided for herein, any consent or approval of the parties shall be made by the governing body of each party.

7.14--Default and Remedies.

Default shall occur only in the event either party fails to adhere to its respective obligations hereunder. In such event, the non-defaulting party shall give the defaulting party written notice describing such default and the proposed date of termination. Such date may not be sooner than the 30th day following receipt of the notice. The non-defaulting party, at its sole option, may extend the proposed date of termination to a later date. If prior to the proposed date of termination, the defaulting party cures such default, then the proposed termination shall not occur. If the defaulting party fails to cure such default prior to the proposed date of termination, then the non-defaulting party may terminate its performance under this Contract as of such date. This Contract shall not be considered as specifying the exclusive remedy for any default but all remedies existing at law and in equity may be availed of by either party and shall be cumulative.

IN WITNESS WHEREOF, the parties hereto have executed this Contract in multiple copies, each of which shall be deemed to be an original.

"HOUSTON"

CITY OF HOUSTON, TEXAS

By: _____
Mayor

Executed for and on behalf of City pursuant to authority granted by the City Council Ordinance No. No. 94-49, passed 1-19-94, 1993, a copy of which is attached hereto for reference.

ATTEST:

_____
City Secretary
(SEAL)

APPROVED:

_____
Director, Department of Public Works and Engineering

APPROVED AS TO FORM:

_____
Sr. Assistant City Attorney

COUNTERSIGNATURE:

_____
City Controller

DATE OF COUNTERSIGNATURE: 2-23-94

"WEST UNIVERSITY"

CITY OF WEST UNIVERSITY PLACE, TEXAS

By: _____
CITY MANAGER

Executed for and on behalf of City of West University Place and its governing body acting by Ordinance No. 1467, passed September 27, 1993, a copy of which is attached hereto for reference, and motion adopted October 11, 1993, copy attached.

ATTEST:

_____
City Secretary
(SEAL)

APPROVED:

_____
Engineer for West University

REVIEWED:

_____
Attorney for West University

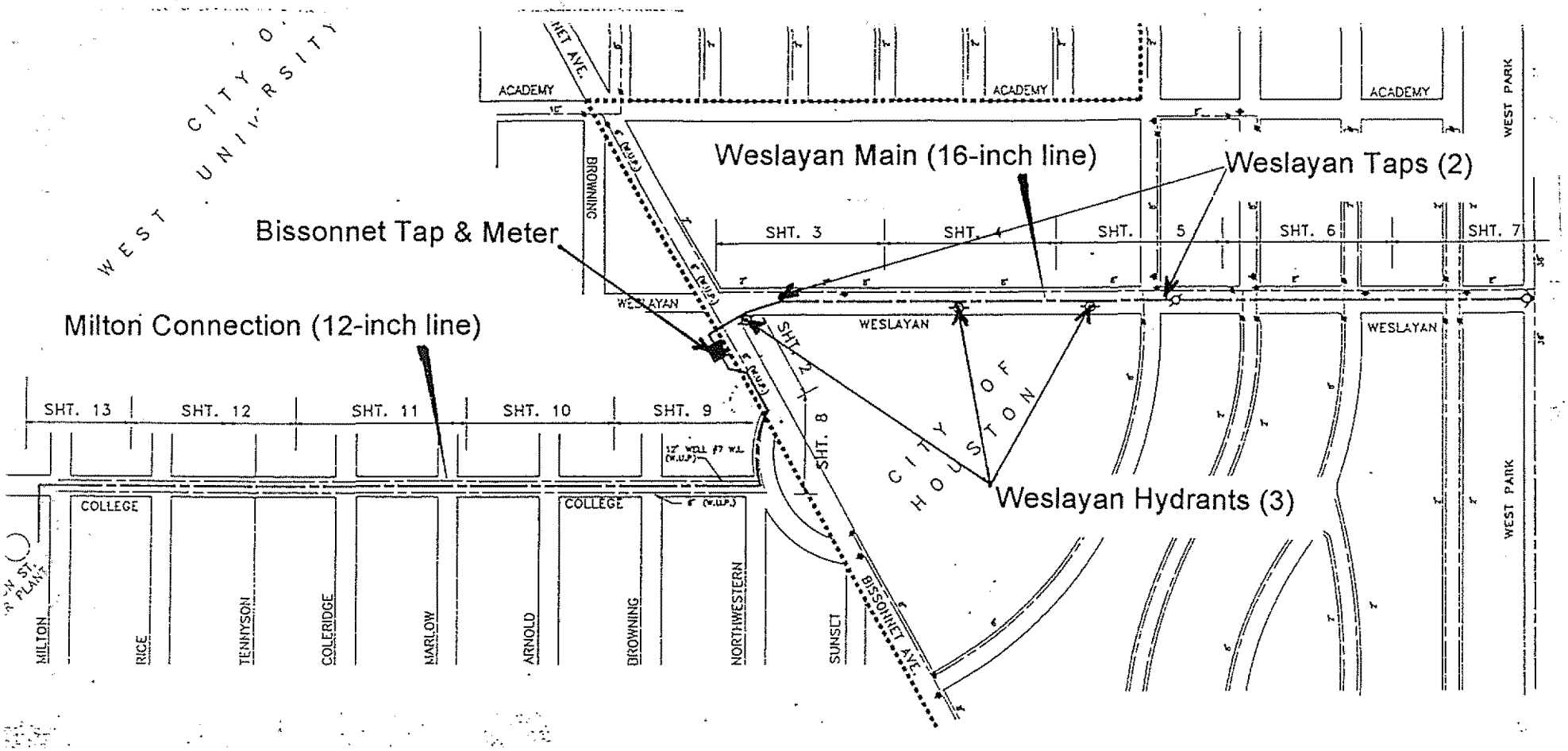
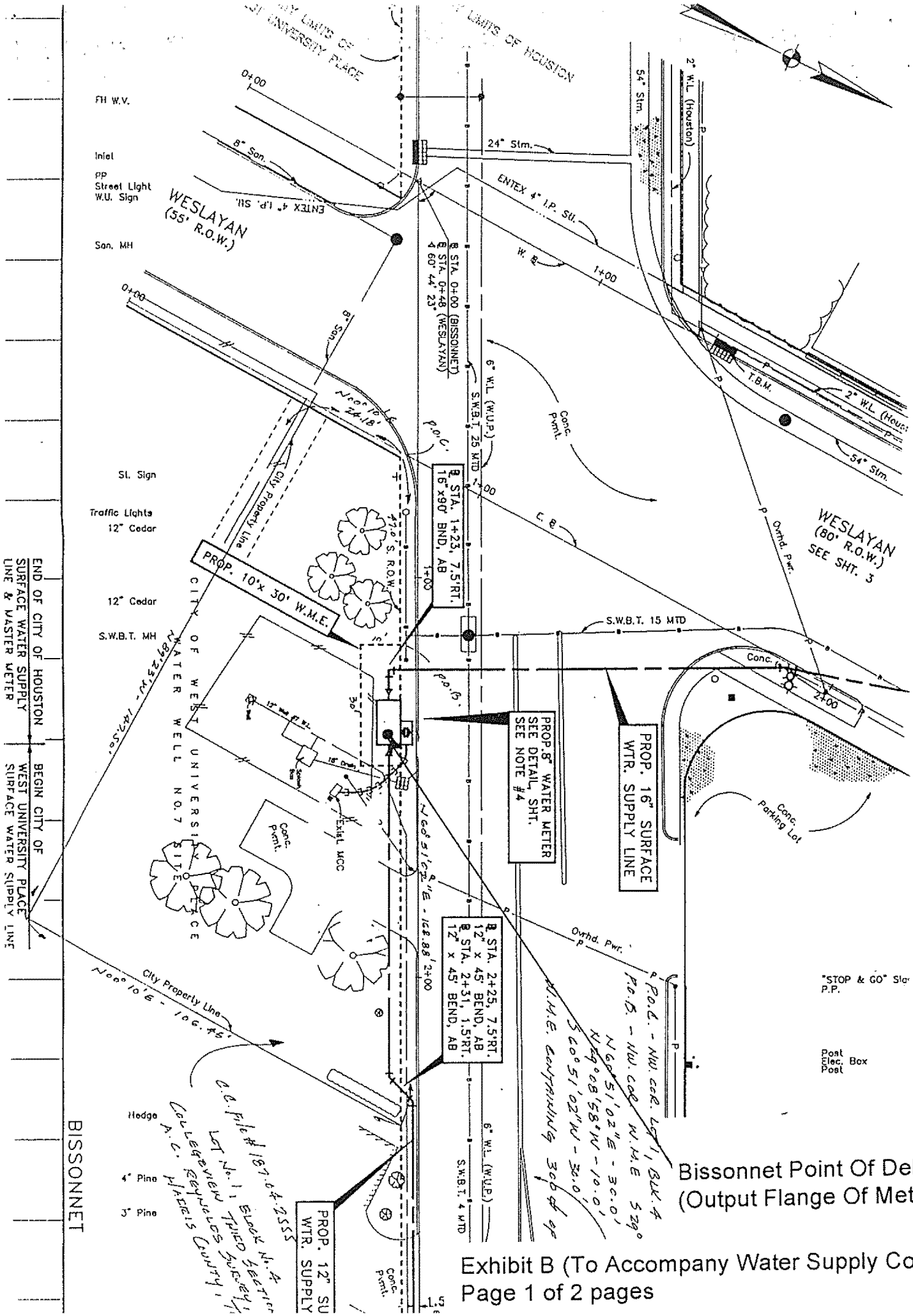
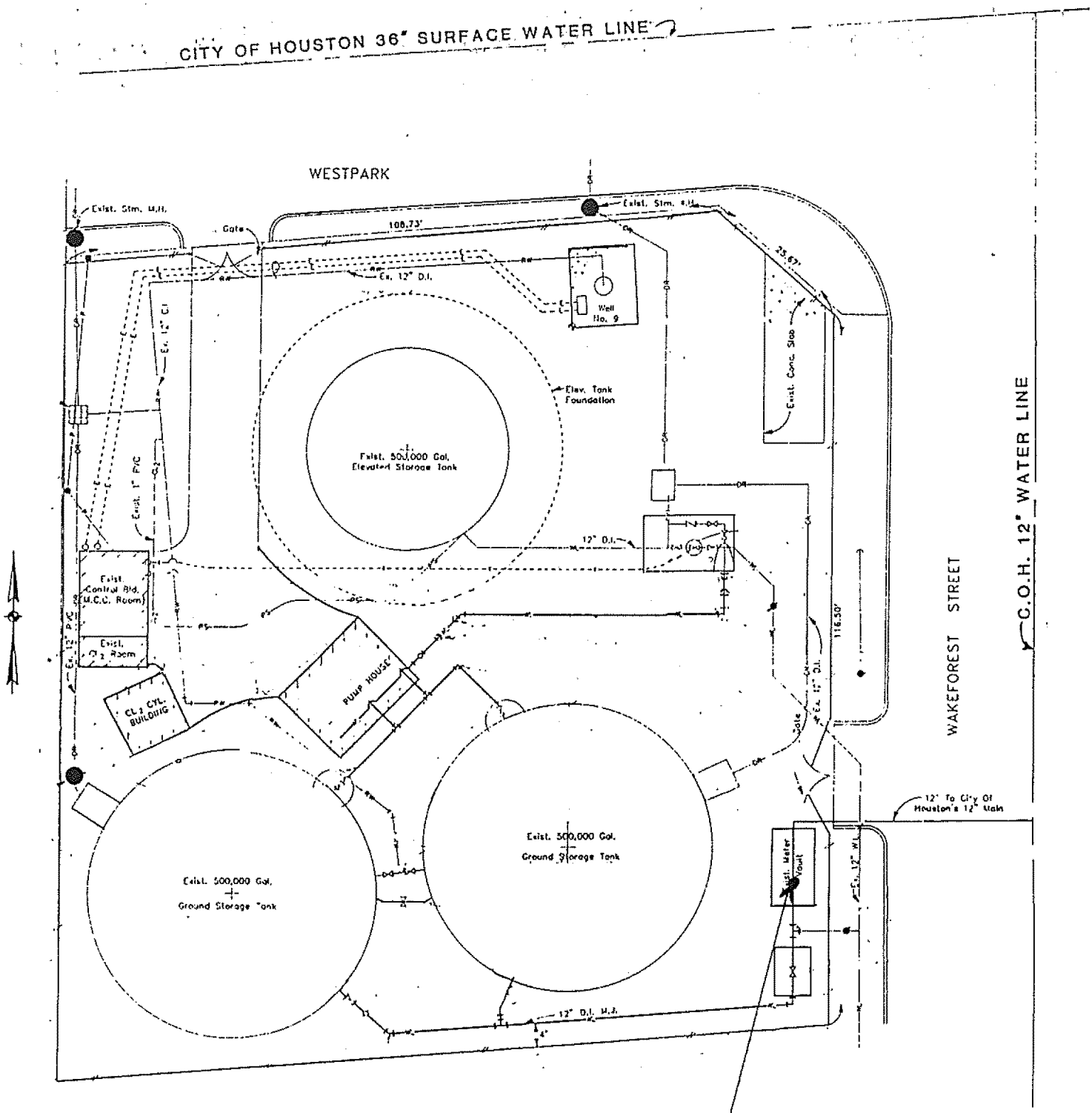


Exhibit A (To Accompany Water Supply Contract


CITY LIMITS OF WEST UNIVERSITY PLACE
CITY LIMITS OF HOUSTON
WESLAYAN (55' R.O.W.)
WESLAYAN (80' R.O.W.) SEE SHT. 3
BISSONNET
CITY OF WEST UNIVERSITY PLACE WATER WELL NO. 7 SITE
END OF CITY OF HOUSTON SURFACE WATER SUPPLY LINE & MASTER METER
BEGIN CITY OF WEST UNIVERSITY PLACE SURFACE WATER SUPPLY LINE
PROP. 10' x 30' W.M.E.
PROP. 16" SURFACE WTR. SUPPLY LINE
PROP. 8" WATER METER SEE DETAIL, SHT. SEE NOTE #4
PROP. 12" SU WTR. SUPPLY
Bissonnet Point Of Delivery (Output Flange Of Meter)
P.O.B. - NW. cor. Lot 1, Blk. 4
P.O.B. - NW. cor. W.M.E.
N89°23'W - 147.5'
N00°10'E - 10.0'
S00°51'02"W - 30.0'
N89°08'58"W - 10.0'
N00°51'02"E - 30.0'
N00°10'E - 106.45'
S89°08'58"E - 168.88'
Ovhd. Pwr.
Conc. Pvmt.
Conc. Parking Lot
Existing MCC
Traffic Lights
St. Sign
Street Light
W.U. Sign
Inlet
San. MH
S.W.B.T. MH
Hedge
4" Pine
3" Pine
12" Cedar
"STOP & GO" Sign
Post
Elec. Box
Post
Exhibit B (To Accompany Water Supply Contrac
Page 1 of 2 pages



WEST UNIV. PLACE

WAKEFOREST

WATER PLANT

Wakeforest Point Of Delivery
(Output Flange Of Meter)

EXHIBIT "C"

BILL OF SALE FOR WATER FACILITIES

THE STATE OF TEXAS §
§
COUNTY OF HARRIS §

KNOW ALL PERSONS BY THESE PRESENTS, that the CITY OF WEST UNIVERSITY PLACE, TEXAS, a municipal corporation and home rule city of the State of Texas ("West University"), subject to the reservations described below, hereby **GRANTS, SELLS AND CONVEYS TO THE CITY OF HOUSTON, TEXAS,** a municipal corporation and home rule city of the State of Texas ("Houston"), title to certain newly-constructed water facilities located within or adjacent to Weslayan Avenue and Bissonnet Street in Harris County, Texas, which water facilities are known as the Weslayan Main, the Weslayan Hydrants, the Weslayan Taps and the Bissonnet Tap & Meter and are more fully described in the attached Exhibit "A". This conveyance is made subject to the following reservations:

(1) West University reserves to itself, its successors and assigns one-half of the conveyance capacity of the Weslayan Main.

(2) When the Bissonnet Tap & Meter (including the vault and all associated items) are no longer used by Houston to supply water to West University, title to the Bissonnet Tap & Meter, as well as any other water facilities conveyed to Houston by this Bill of Sale and located inside the boundaries of West University, shall automatically revert to West University, its successors and assigns, it being recognized that they are located upon property owned by West University and are not intended to be removed.

(3) This conveyance is made subject to that certain "Water Supply Contract Between the City of Houston and the City of West University Place, Texas" countersigned by the Controller of the City of Houston on 1-19, 1994

EXECUTED this 17th day of November, 1993.

CITY OF WEST UNIVERSITY PLACE, TEXAS

By: _____
Name: MIKE TANNER
Title: CITY MANAGER

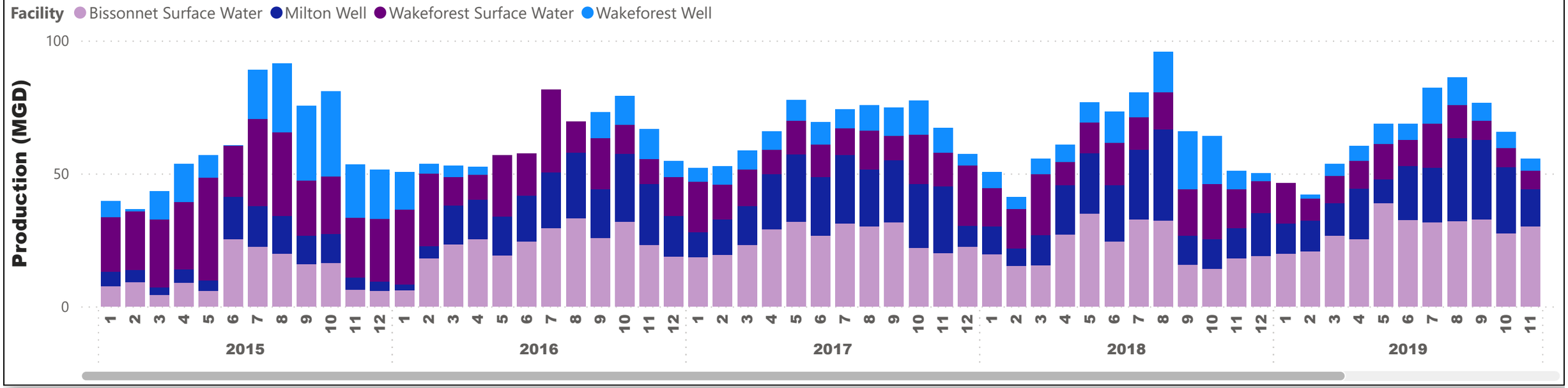
ATTEST/SEAL:

By: _____
Name: KAYLYNN HOLLOWAY
Title: CITY SECRETARY

APPENDIX C
Historical Water Production

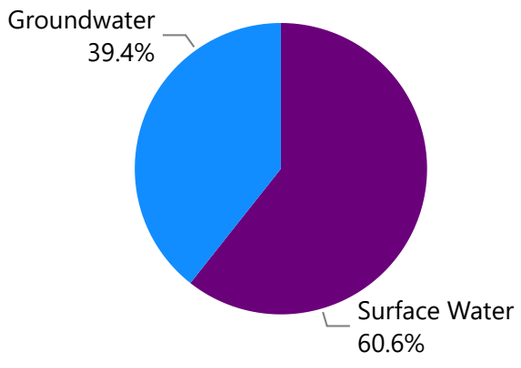
City of West University Place
Water System Assessment
Historical Water Production

Historical Water Production

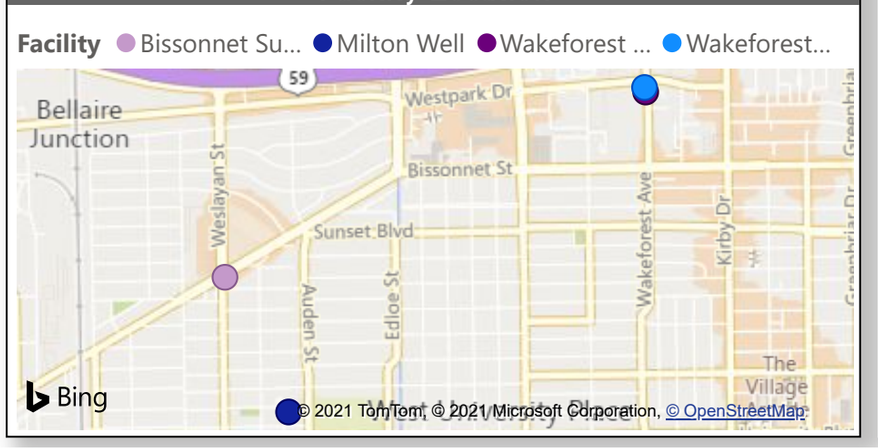


Year	Average Day Demand (MGD)	Max Day Demand (MGD)
2015	2.07	4.51
2016	2.12	4.36
2017	2.20	5.12
2018	2.17	5.56
2019	2.17	4.28
2020	2.17	5.61

Water Source



Facility Location



Facility ID

- [ ] Bissonnet Surface Water
- [ ] Milton Well
- [ ] Wakeforest Surface Water
- [ ] Wakeforest Well

APPENDIX D
Field Pressure Testing Results

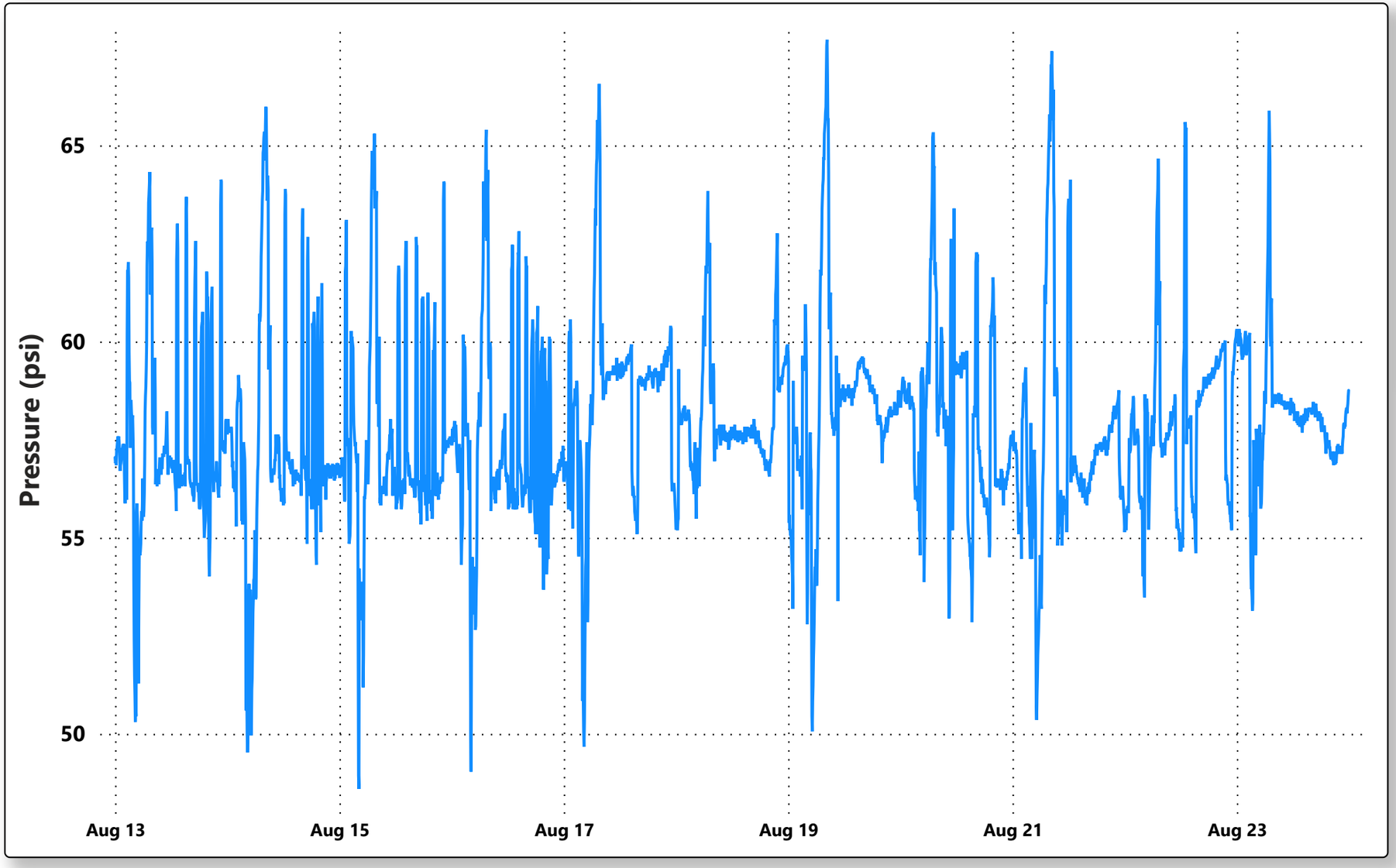
City of West University Place

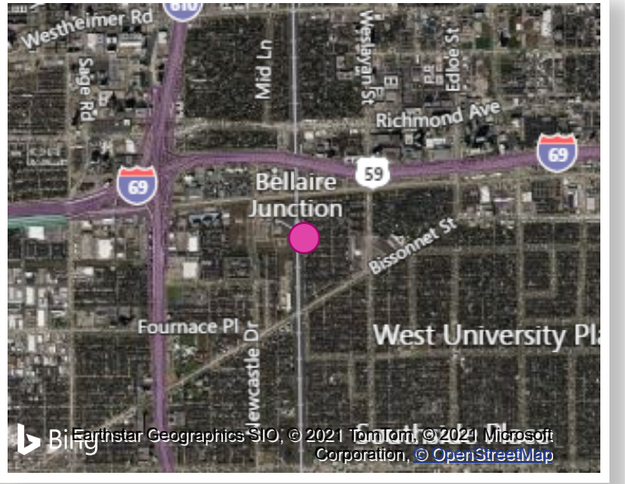
FREESE AND NICHOLS

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-01

8/13/2020 — 8/23/2020





Address

4256 Albans Rd

Elevation (ft)

55.7

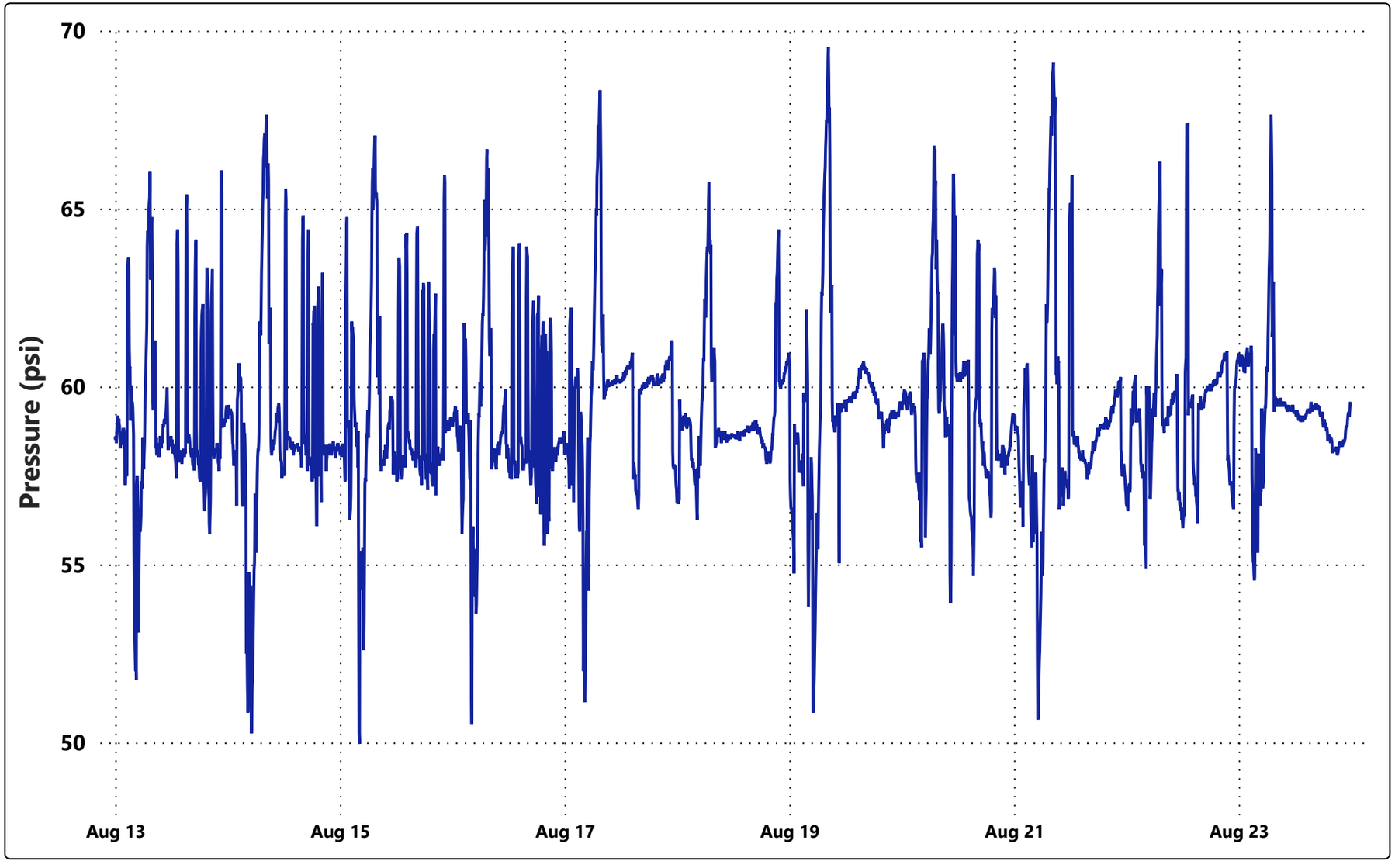
Pressure Statistics

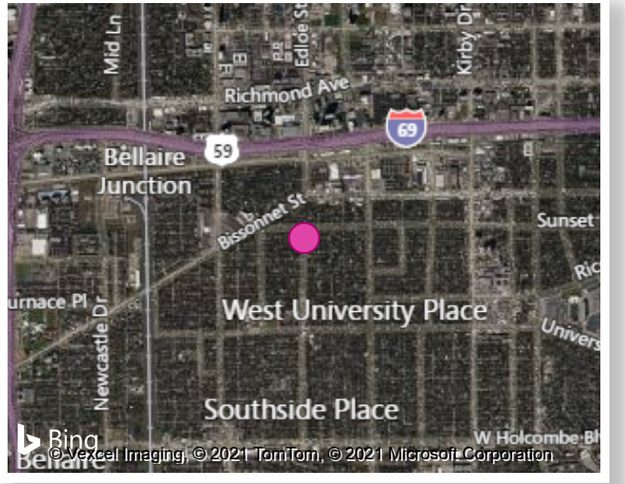
Min: 49 psi
Max: 68 psi
Avg: 58 psi

- [x] PR-01
- [ ] PR-02
- [ ] PR-03
- [ ] PR-04
- [ ] PR-05
- [ ] PR-06
- [ ] PR-07
- [ ] PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results
Pressure Recorder: PR-02

8/13/2020 8/23/2020





Address

3701 Nottingham

Elevation (ft)

56.7

Pressure Statistics

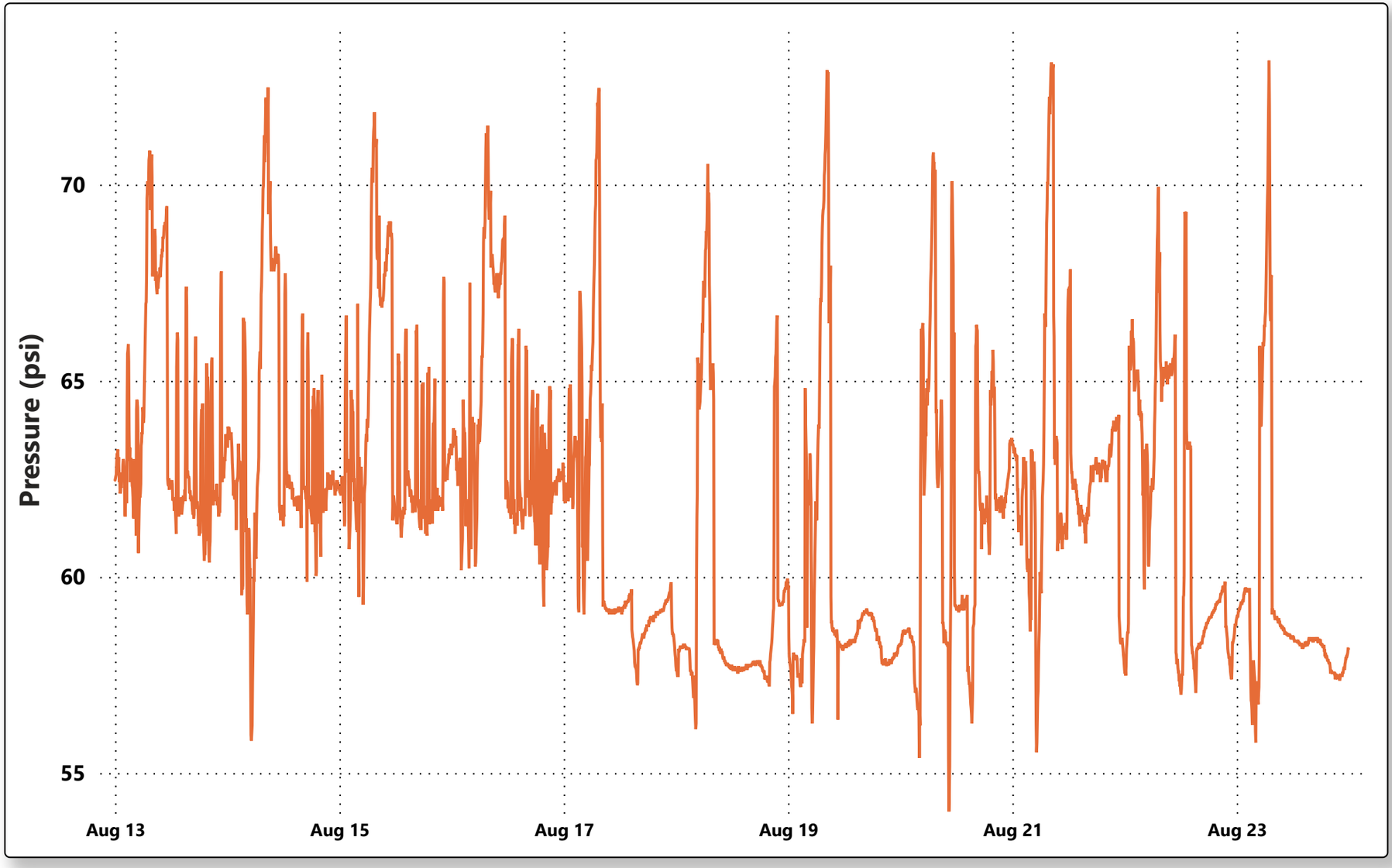
Min: 50 psi
Max: 70 psi
Avg: 59 psi

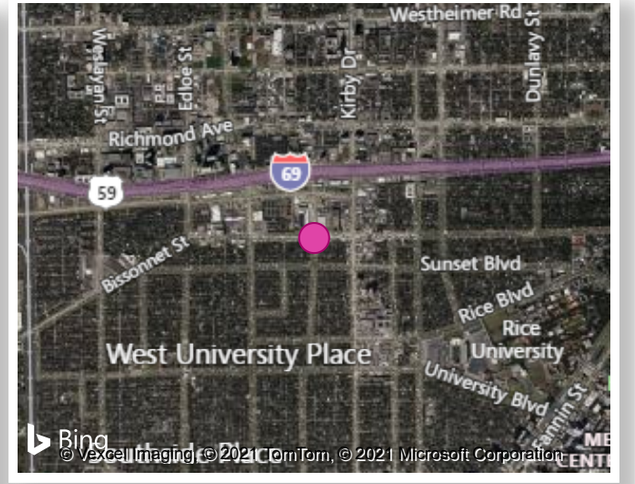
- ☐ PR-01
- ■ PR-02
- ☐ PR-03
- ☐ PR-04
- ☐ PR-05
- ☐ PR-06
- ☐ PR-07
- ☐ PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-03

8/13/2020 — 8/23/2020





Address

Wakeforest Water Plant

Elevation (ft)

52.8

Pressure Statistics

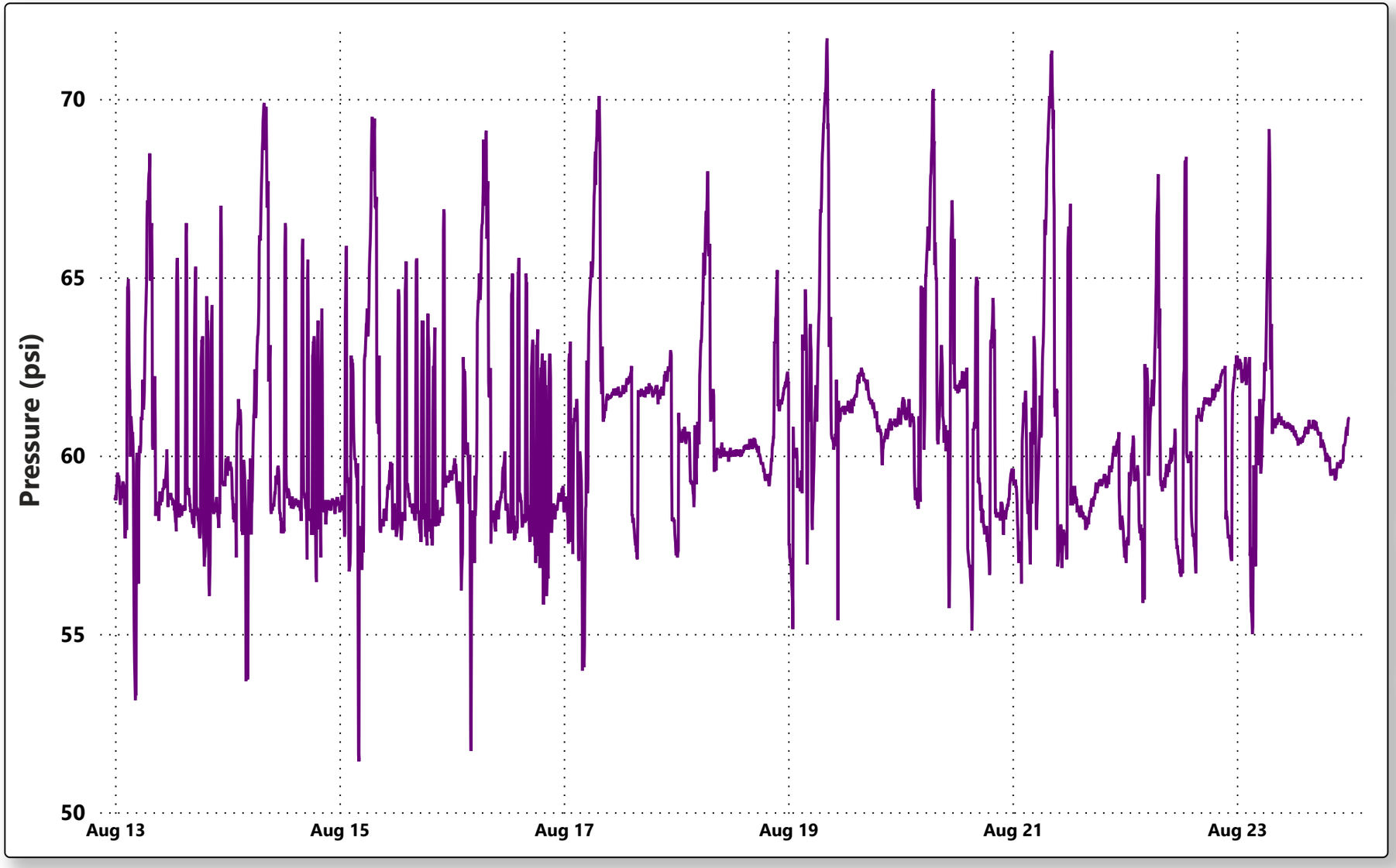
Min: 54 psi
Max: 73 psi
Avg: 62 psi

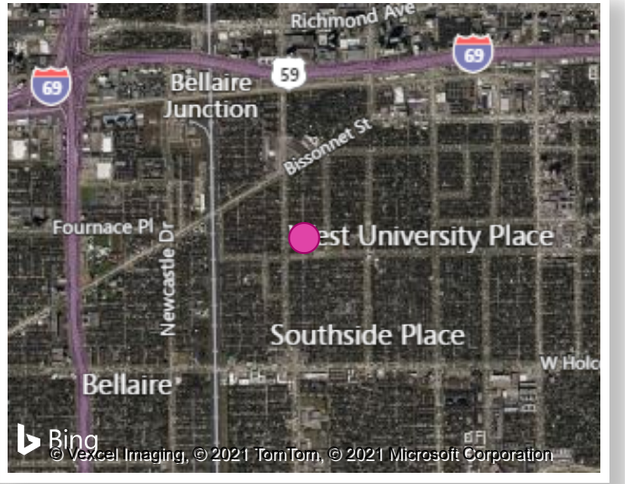
- ☐ PR-01
- ☐ PR-02
- ■ PR-03
- ☐ PR-04
- ☐ PR-05
- ☐ PR-06
- ☐ PR-07
- ☐ PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-04

8/13/2020 8/23/2020





Address

Milton Water Plant

Elevation (ft)

57.9

Pressure Statistics

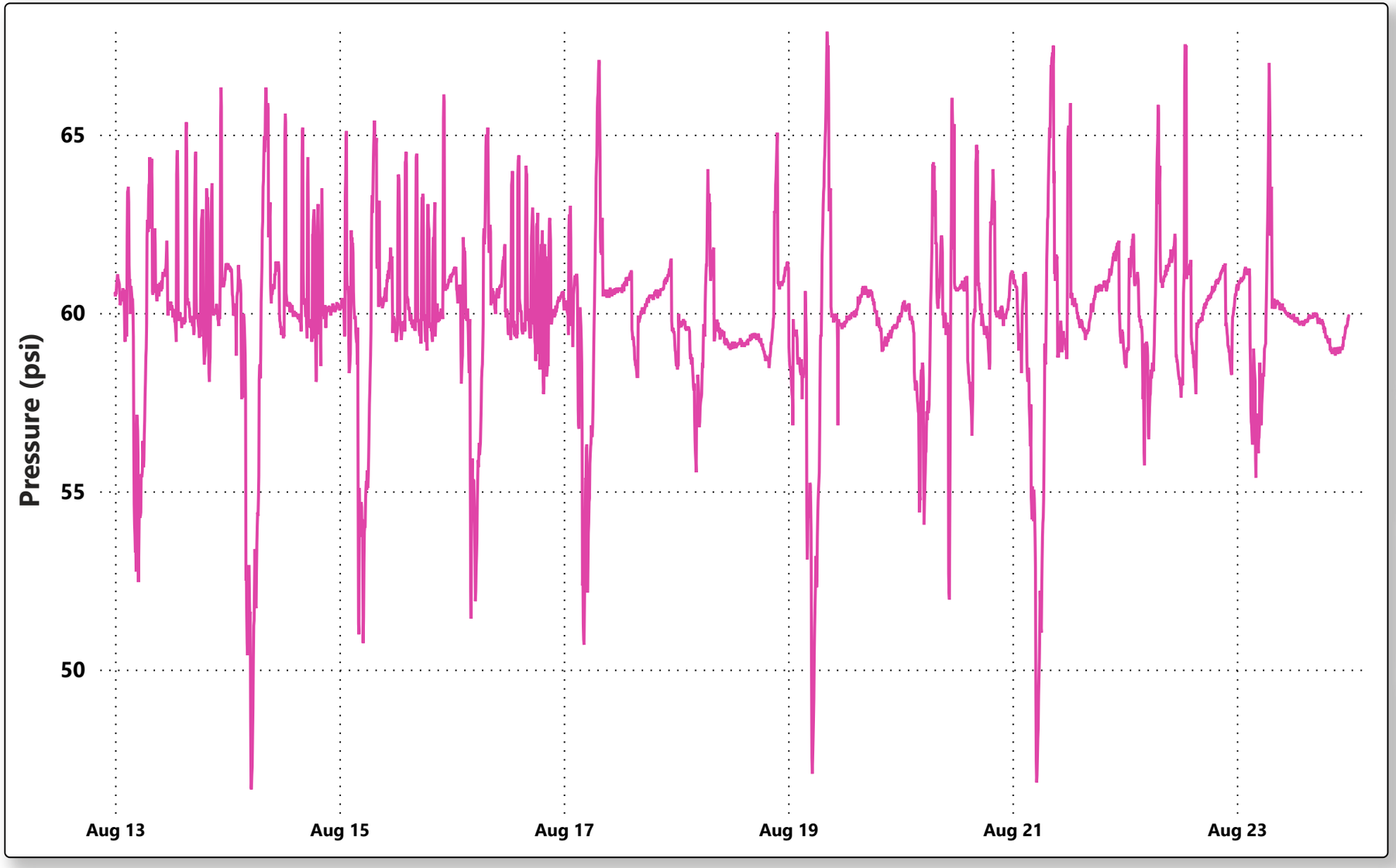
Min: 51 psi
Max: 72 psi
Avg: 61 psi

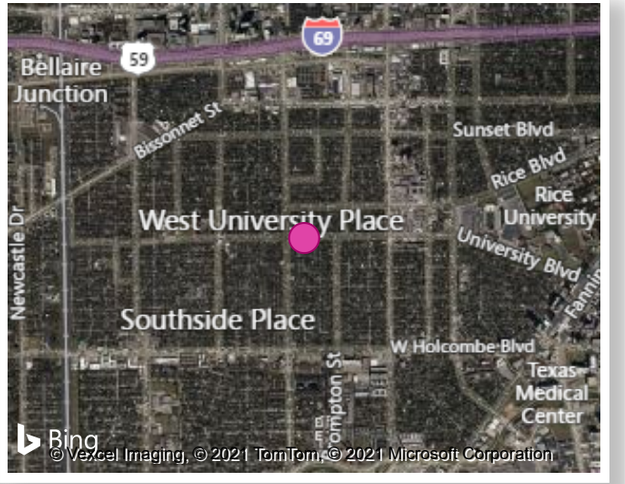
- ☐ PR-01
- ☐ PR-02
- ☐ PR-03
- ■ PR-04
- ☐ PR-05
- ☐ PR-06
- ☐ PR-07
- ☐ PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-05

8/13/2020 — 8/23/2020





Address

3025 University

Elevation (ft)

55.8

Pressure Statistics

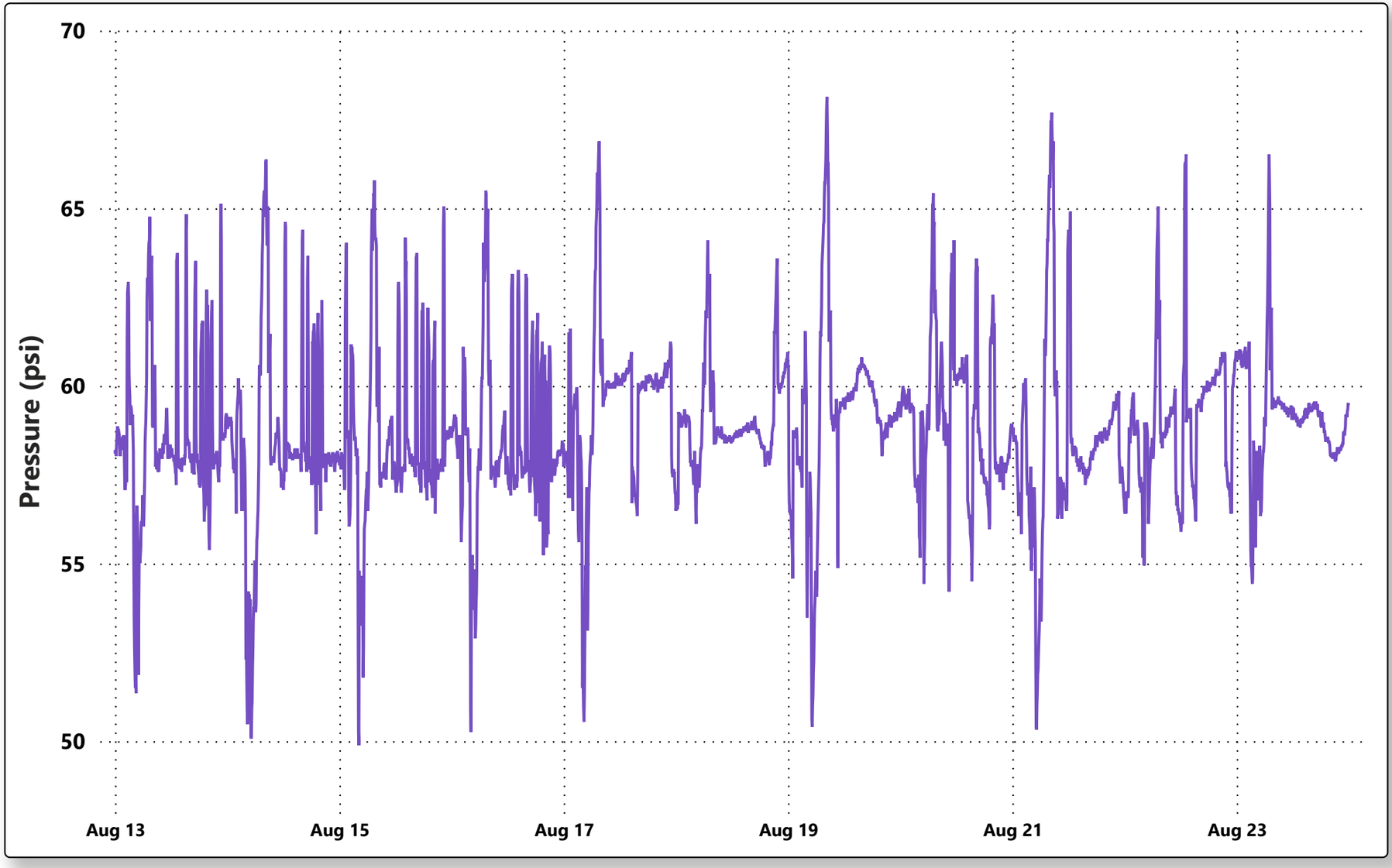
Min: 47 psi
Max: 68 psi
Avg: 60 psi

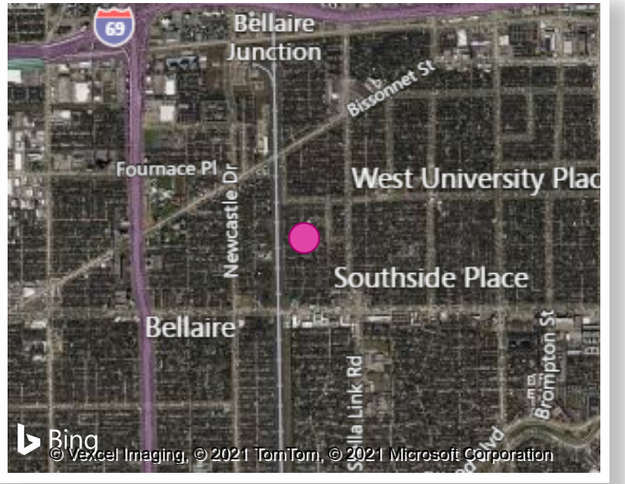
- PR-01
- PR-02
- PR-03
- PR-04
- **PR-05**
- PR-06
- PR-07
- PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-06

8/13/2020 — 8/23/2020





Address

4153 Oberlin

Elevation (ft)

59.2

Pressure Statistics

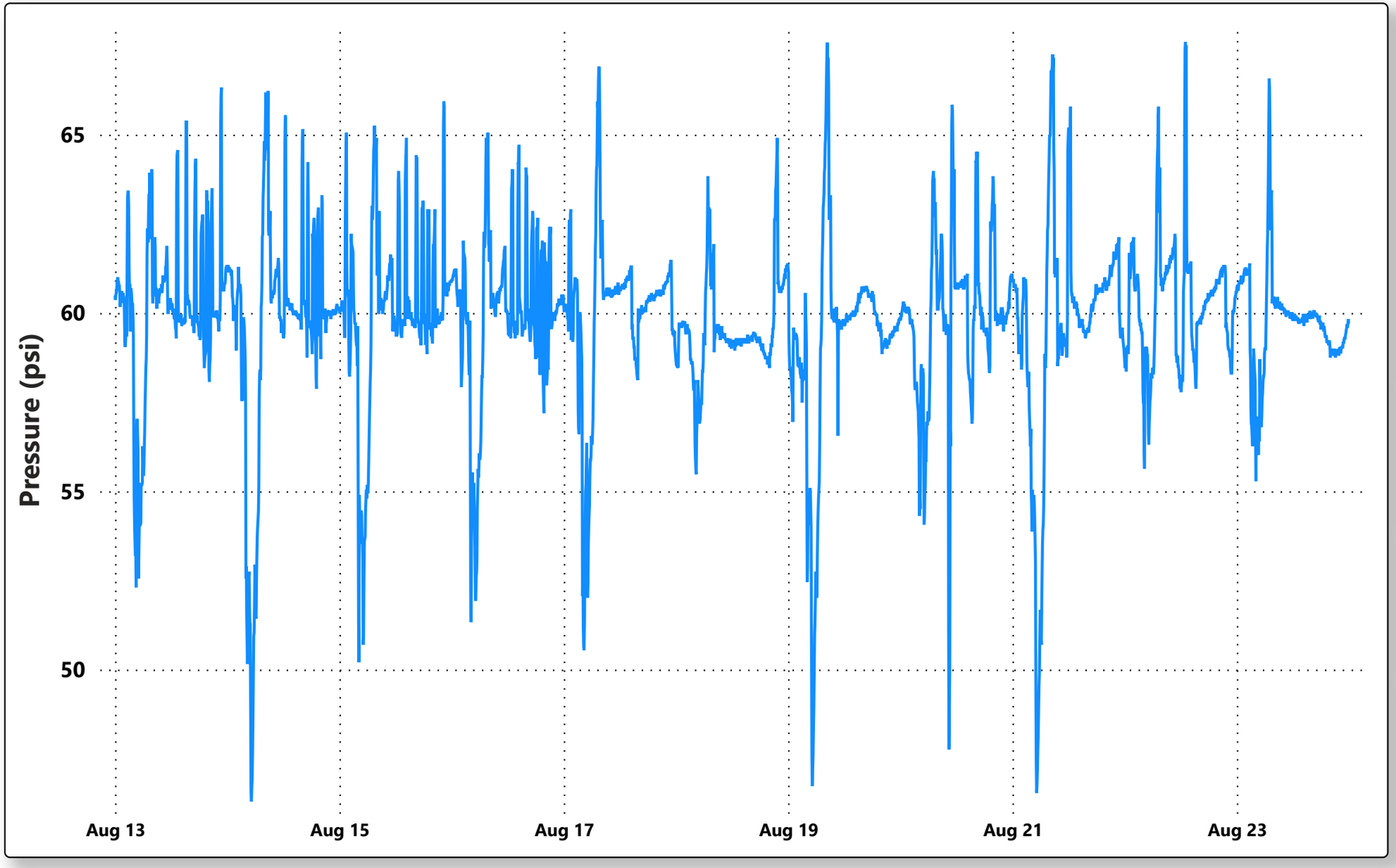
Min: 50 psi
Max: 68 psi
Avg: 59 psi

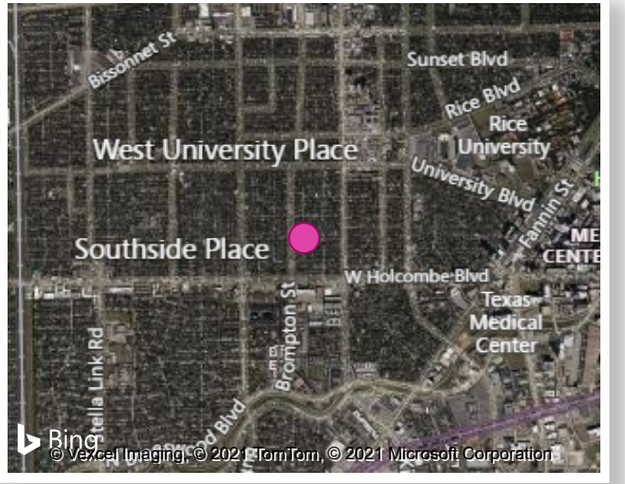
- ☐ PR-01
- ☐ PR-02
- ☐ PR-03
- ☐ PR-04
- ☐ PR-05
- ■ PR-06
- ☐ PR-07
- ☐ PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-07

8/13/2020 — 8/23/2020





Address

2737 Arbuckle

Elevation (ft)

56.3

Pressure Statistics

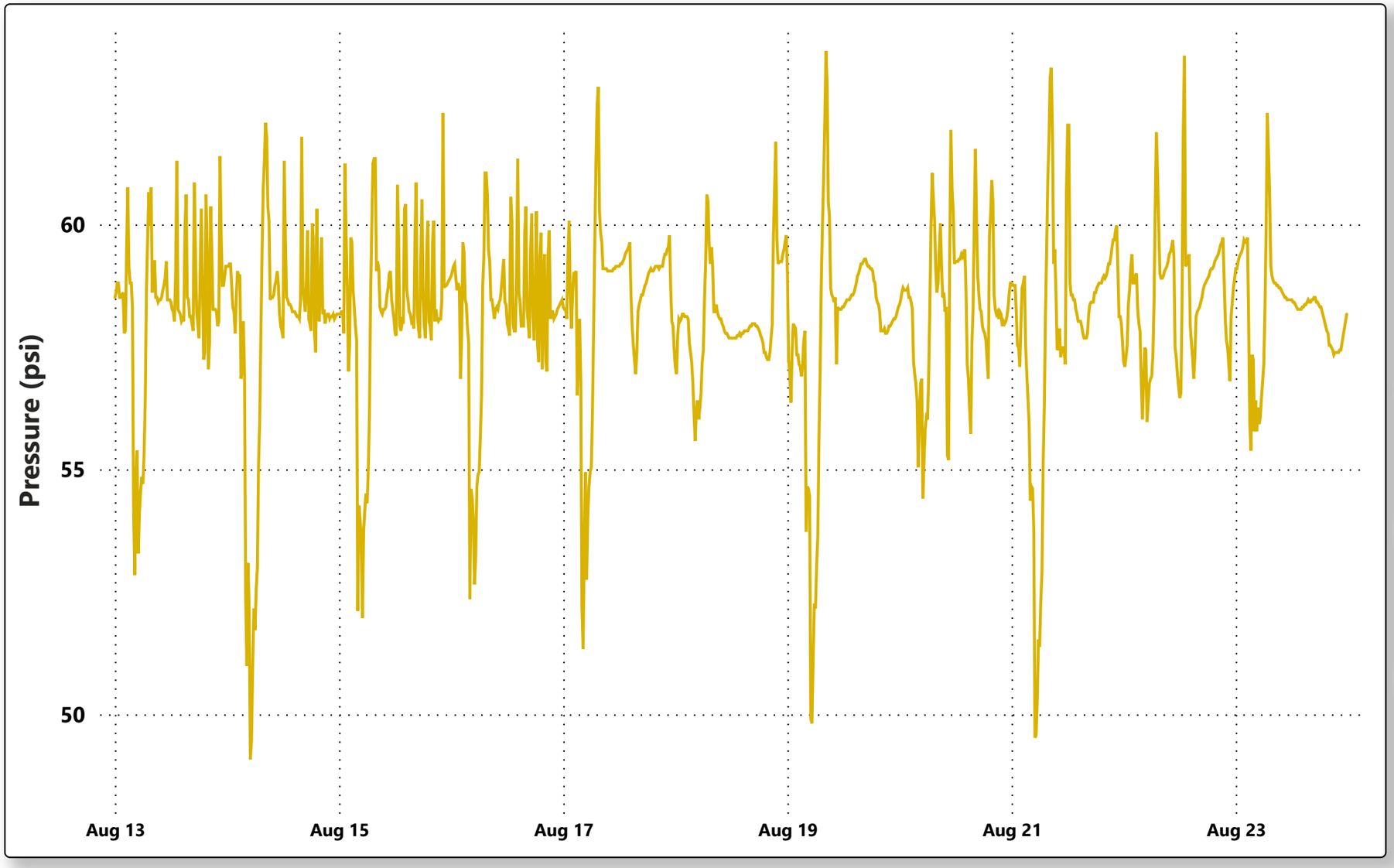
Min: 46 psi
Max: 68 psi
Avg: 60 psi

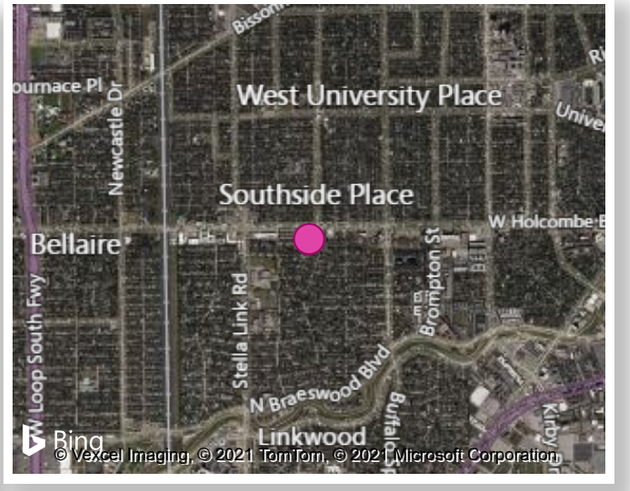
- ☐ PR-01
- ☐ PR-02
- ☐ PR-03
- ☐ PR-04
- ☐ PR-05
- ☐ PR-06
- ■ PR-07
- ☐ PR-08

City of West University Place
Water System Assessment
Field Pressure Testing Results

Pressure Recorder: PR-08

8/13/2020 — 8/23/2020





Address

Bellaire EST

Elevation (ft)

59.2

Pressure Statistics

Min: 49 psi
Max: 64 psi
Avg: 58 psi

- ☐ PR-01
- ☐ PR-02
- ☐ PR-03
- ☐ PR-04
- ☐ PR-05
- ☐ PR-06
- ☐ PR-07
- ■ PR-08

APPENDIX E
Booster Pump Field Testing Reports
(by Smith Pump)

MILTON STREET PUMP STATION FIELD ASSESSMENT

CONTRACTOR: N/A

ENGINEER: Freese & Nichols, Inc.

OWNER: **CITY OF WEST UNIVERSITY PLACE**

PUMP STATIONS: Milton Street Pump Station

SPECIFICATIONS: NONE

EQUIPMENT: P-1 & P-2
American-Marsh HIM, Size 6, 1 Stg HSC, 1,400 gpm @ 175' TDH, 1,750 rpm, Serial No: Unknown / 04-5916 **|** Howell Horizontal Motor, 75 hp, 1,770 rpm, 440 V, 86.5 FLA, Serial #: 155042039 / TECO Horizontal Motor, 100 hp, 1,780 rpm, 460 V, 115 FLA, Serial #: Unknown

P-3
Fairbanks-Morse 1823, 6", 1 Stg HSC, Serial No: Unknown **|** Fairbanks-Morse Horizontal Motor, 60 hp, 1,765 rpm, 440 V, 71 FLA, Serial #: F356340

P-4
ITT A-C 8100, 8x6x12L, 1 Stg HSC, 1,500 gpm @ 132' THD, 1,775 rpm, Serial No: 1-74417-01-1 **|** USEM Horizontal Motor, 60 hp, 1,785 rpm, 460 V, 70 FLA, Serial #: F07-H649-M

Smith Pump Company, Inc.

REVISION RECORD

REVISION	DATE	DESCRIPTION	BY
0	11/18/2020	Initial Release	S. Wallace

EXECUTIVE SUMMARY

BP-1 motor vibration signatures show possible looseness which is generally caused by worn bearings. It is unclear how the pump is performing as the catalog curve could not be found but the nameplate shows 1,400 gpm at 175 ft and, according to the test, the trend line is significantly lower than this. The rest of the pump appears to be in good condition with no significant vibration. It is recommended the motor be pulled and inspected and the pump be disassembled to determine the cause for the significant loss in performance.

BP-2 motor vibration signatures show a potential electrical fault though it does not seem to be too significant at this point. It is unclear how the pump is performing as the catalog curve could not be found but the nameplate shows 1,400 gpm at 175 ft and, according to the test, the trend line is significantly lower than this. The rest of the pump appears to be in good condition with no significant vibration. It is recommended the motor be pulled and inspected and the pump be disassembled to determine the cause for the significant loss in performance.

BP-3 pump appears to be operating close to the catalog curve if the curve selected is correct and the pump is operating with low vibration. The motor appears to have a slight electrical fault with a potential bearing fault but nothing to be too concerned about and is operating well. If the pump catalog curve is correct, the motor horsepower will be exceeded if the flow rate exceed 1,400 gpm.

BP-4 pump operates close to the catalog curve and with low vibration. The motor operates very well with low vibration. The only issue is that the motor rated horsepower will be exceeded when the flow rate exceeds 1,300 gpm. If the flow is expected to exceed 1,300 gpm, it is recommended the existing motor be replaced with a larger one, 75 hp recommended.

REPORT OUTLINE

GENERAL ARRANGEMENT

There are four (4) horizontal split case pumps at this station. Two (2) pumps are of one size and two (2) pumps are of another size. All units are run across the line at a constant speed.

The catalog curve for Pump #4 can be found below. There is not enough information on the other units to find the pump catalog curves.

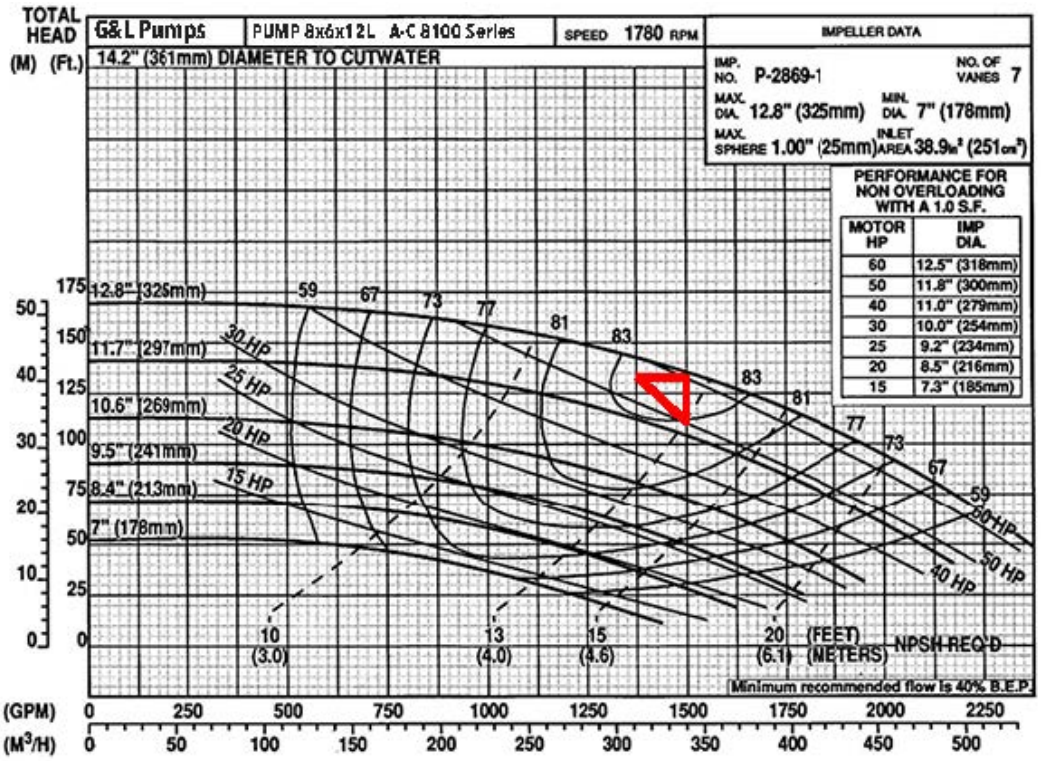


Figure 1: BP-4 Catalog Curve

TYPES OF TESTS

Smith Pump performed a Pump Performance Test, Vibration Test, and a Visual Inspection on each unit. The details of each test are outlined below.

Pump Performance Test

- Test pump at full speed with a 100% open valve and two points with a partially closed valve.
- Record shaft speed (rpm), flow rate, wet well level, discharge pressure, and power.

Vibration Test

- Measure filtered vibration spectra and overall vibration values in three (3) orthogonal planes at the motor non-drive end (NDE) bearing housing, two (2) orthogonal planes at the motor drive end (DE) bearing housing, two (2) orthogonal planes at the pump DE bearing housing, and three (3) orthogonal planes at the motor NDE bearing housing.

Visual Inspection

- Review baseplate design, material conditions, and piping.

ACCEPTANCE CRITERIA

None

TESTING VARIANCES

None

TESTING ARRANGEMENT

(calibration data can be found in Appendix B)

- Flow Rate – Recorded with Smith Pump's GE Panametrics PT878 portable strap-on flowmeter with the serial number 02368. The flow meter was located on the suction field line before the suction header.

- Suction Pressure – The suction pressure was recorded with an Omega Engineering PX459-050A5V pressure transducer which measures from 0 to 50 psia; the serial number is 466962. This transducer was located on the suction of each pump. When the pressure gauge could not be removed, the pump station gauge on the pump was used.

- Discharge Pressure – Recorded with Smith Pump's Winchester Model 1 digital pressure gauge with a range of 30 in Hg to 3,000 psi. The serial number for this gauge is 44518. The pressure gauge was located on the discharge of each pump. When the pressure gauge could not be removed, the pump station gauge on the pump was used.

- Shaft Speed – Recorded with Smith Pump's Monarch AFG3021B tachometer. The serial number of this device is 1520757.

- Vibration – Recorded using Smith Pump's Pruftechnik VibXpert VIB 5.300. The serial number of this device is 00558.

- Power – Recorded using a rented Fluke 1738 3-phase power quality logger. The serial number for this device is 35273147.

TEST RESULTS

The composite curve in Figure 2 below shows field data points plotted against the original factory test curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Recorded using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	American Marsh	**Rated Capacity**	[gpm]	1,400	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	175	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	HIM, Size 6	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,750	**Witnessed By**	
Tag Number	P-1	**Serial Number**	Unknown	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

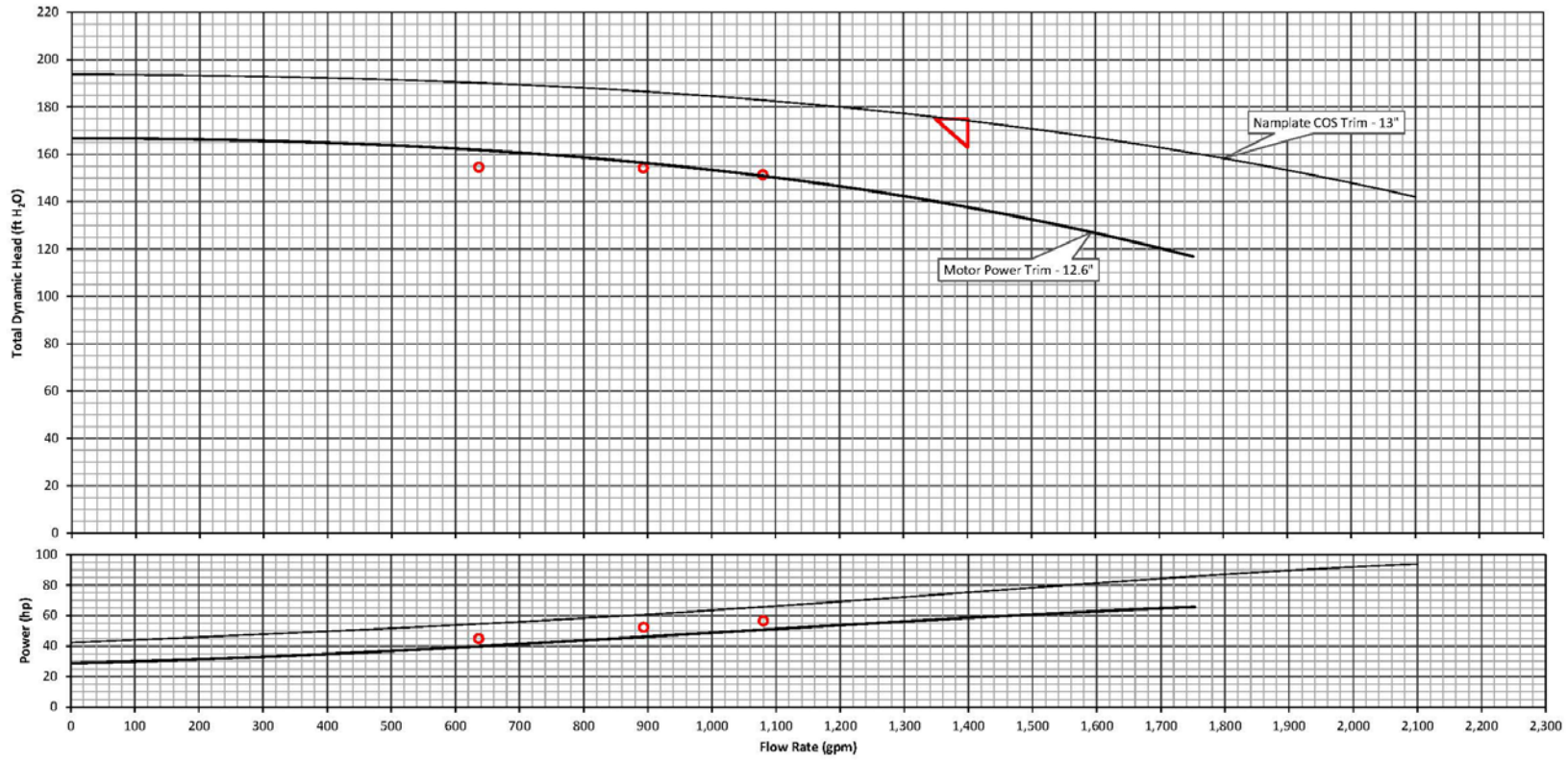


Figure 2: BP-1 Field Test Data

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-1. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the factory test curves at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below in Figure 3 to Figure 12 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

The motor spectrums have a high number of run speed harmonics which tends to indicate a looseness issue.

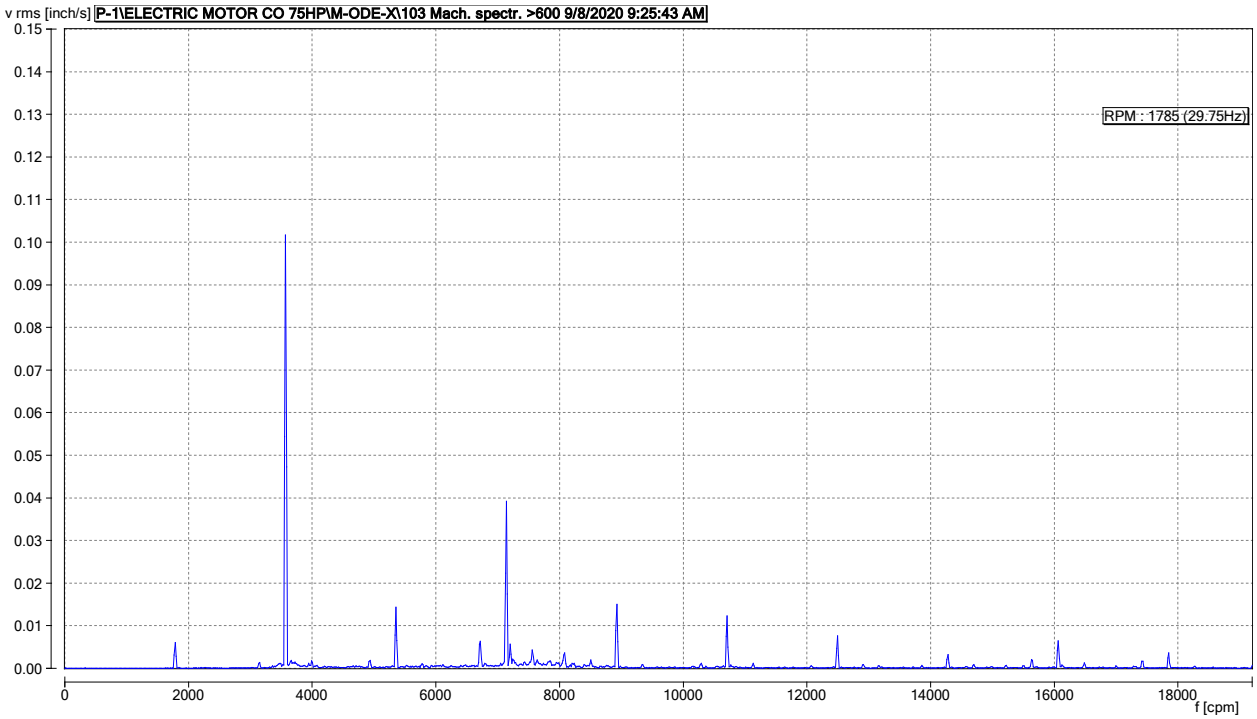


Figure 3: BP-1, M-ODE-X. Maximum peaks are 0.102 in/sec rms at 3,570 cpm (2X run speed) and 0.039 in/sec rms at 7,140 cpm (4X run speed). Other peaks occur at 3X, 5X, 6X, 7X, and 9X run speed.

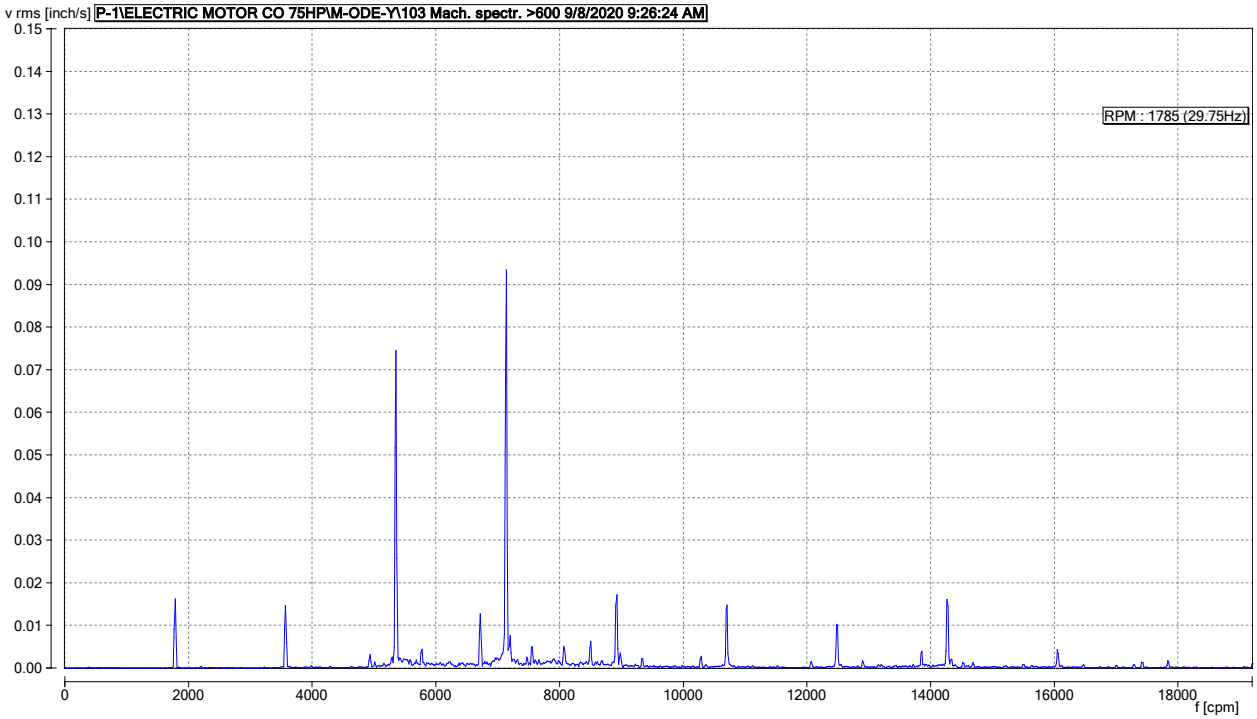


Figure 4: BP-1, M-ODE-Y. Maximum peaks are 0.093 in/sec rms at 7,136 cpm (4X run speed) and 0.074 in/sec rms at 5,351 cpm (3X run speed). The 3X and 4X peaks have sidebands at 420 cpm. Other peaks occur at 1X, 2X, 5X, 6X, 7X, and 8X run speed.

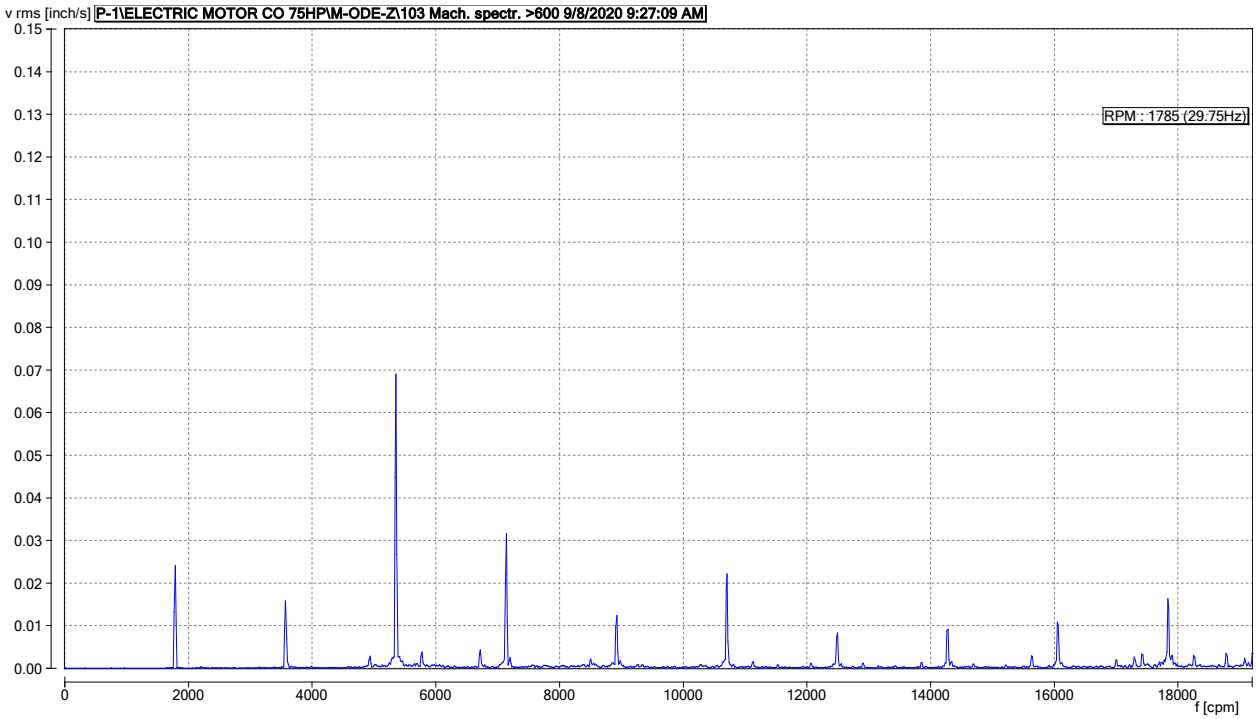


Figure 5: BP-1, M-ODE-Z. Maximum peaks is 0.069 in/sec rms at 5,351 cpm (3X run speed). Other peaks occur at 1X, 2X, 4X, 5X, 6X, 7X, 9X, and 10X run speed.

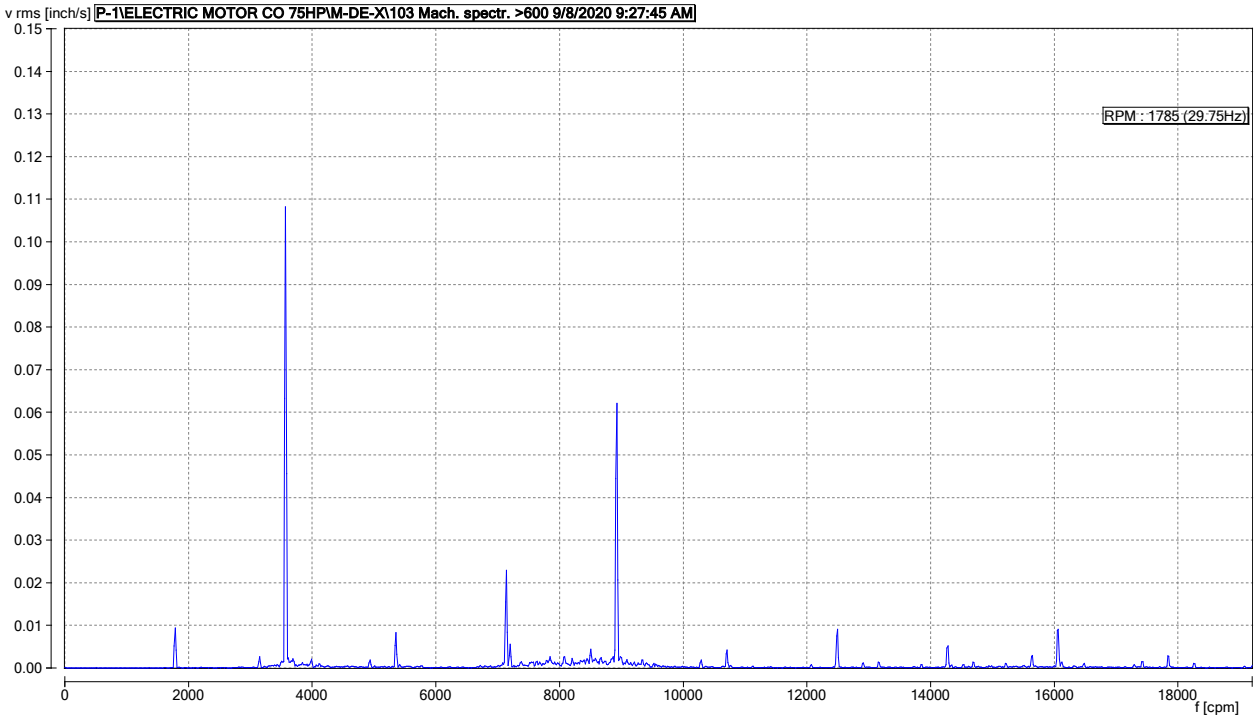


Figure 6: BP-1, M-DE-X. Maximum peaks are 0.108 in/sec rms at 3,570 cpm (2X run speed) and 0.062 in/sec rms at 8,921 cpm (5X run speed). Another peak occurs at 4X run speed.

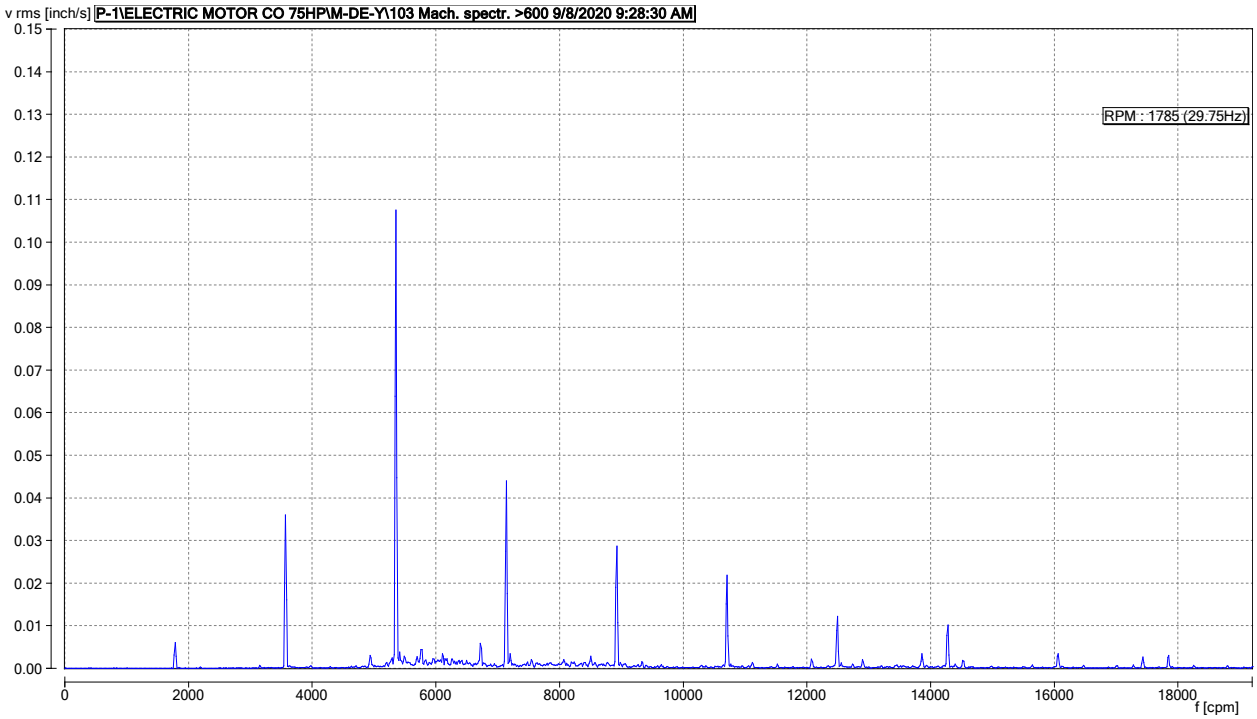


Figure 7: BP-1, M-DE-Y. Maximum peaks are 0.107 in/sec rms at 5,351 cpm (3X run speed), 0.044 in/sec rms at 7,136 cpm (4X run speed), and 0.036 in/sec rms at 3,570 cpm (2X run speed). Other peaks occur at 5X, 6X, 7X, and 8X run speed.

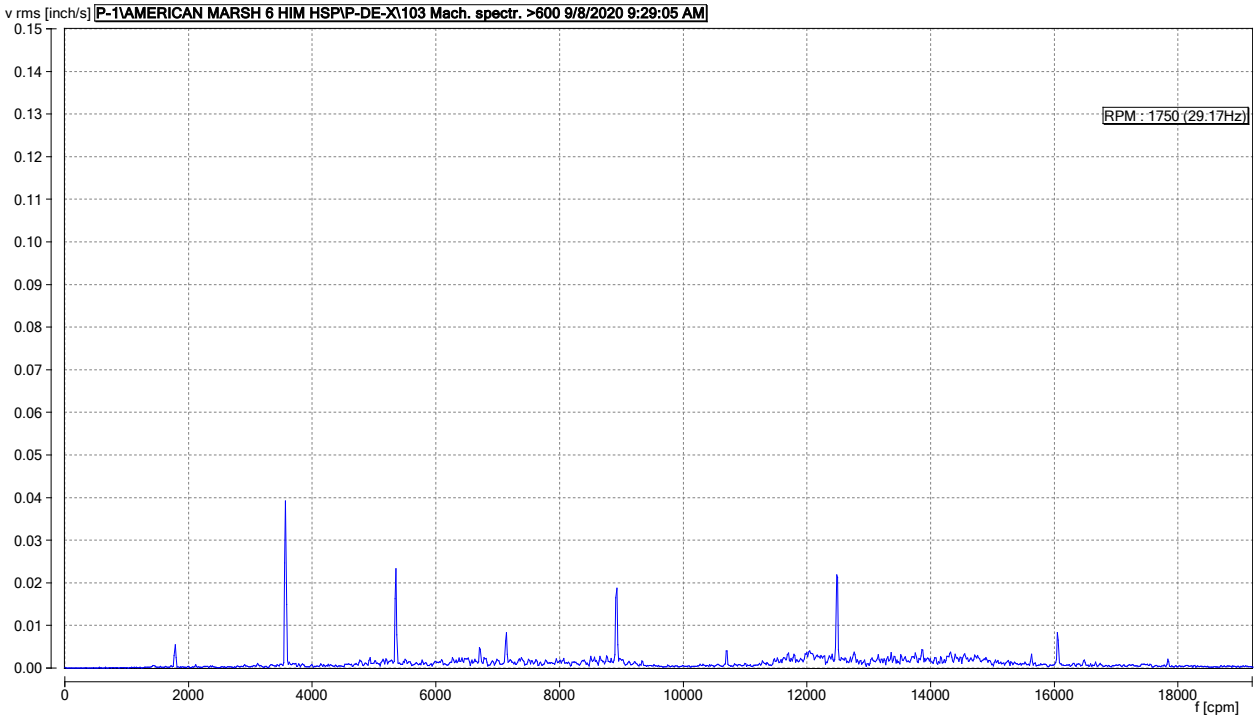


Figure 8: BP-1, P-DE-X. Maximum peaks are 0.039 in/sec rms at 3,566 cpm (2X run speed), 0.023 in/sec rms at 5,351 cpm (3X run speed), and 0.022 in/sec rms at 12,488 cpm (7X run speed). Another peak occurs at 5X run speed.

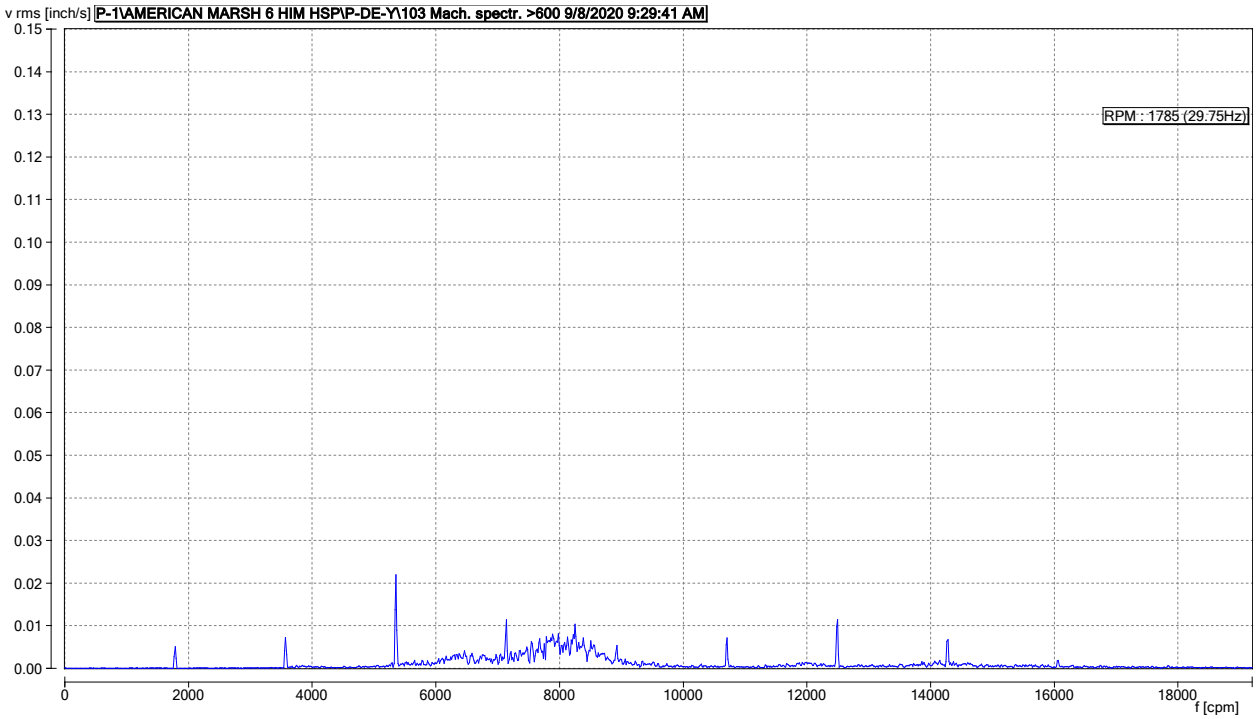


Figure 9: BP-1, P-DE-Y. Maximum peak is 0.022 in/sec rms at 5,351 cpm (3X run speed).

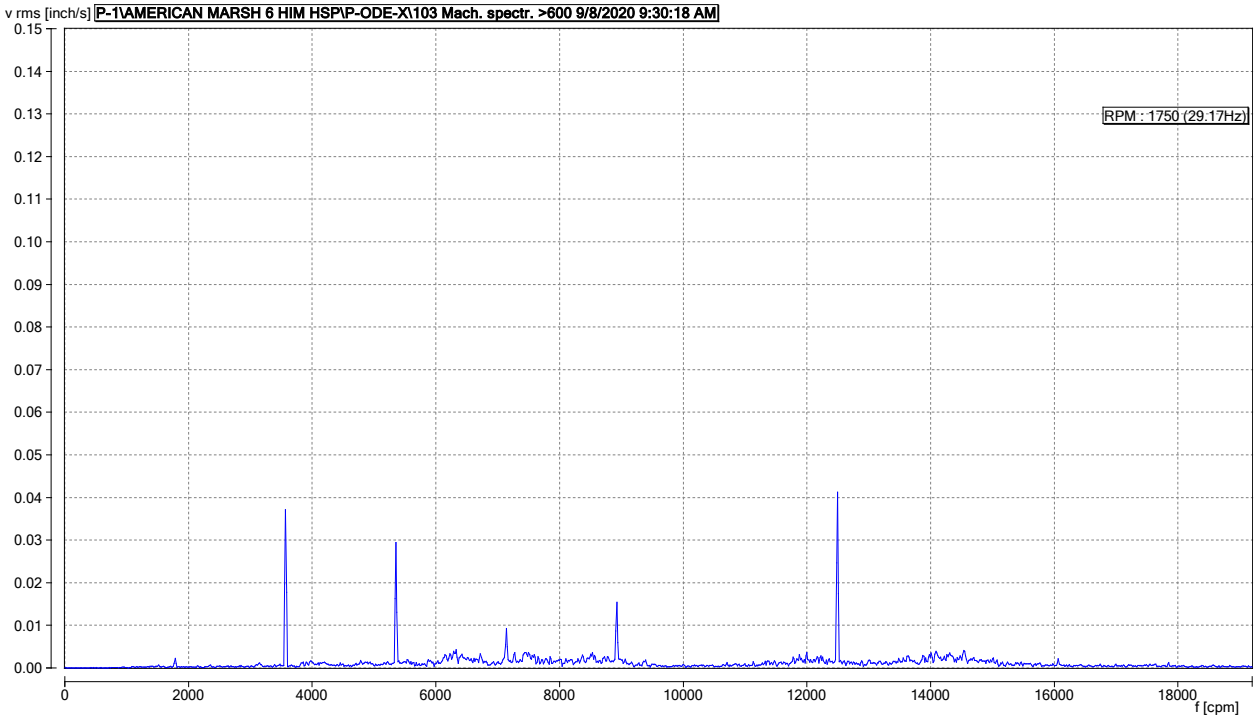


Figure 10: BP-1, P-ODE-X. Maximum peaks are 0.041 in/sec rms at 12,491 cpm (7X run speed), 0.037 in/sec rms at 3,570 cpm (2X run speed), and 0.029 in/sec rms at 5,355 cpm (3X run speed).

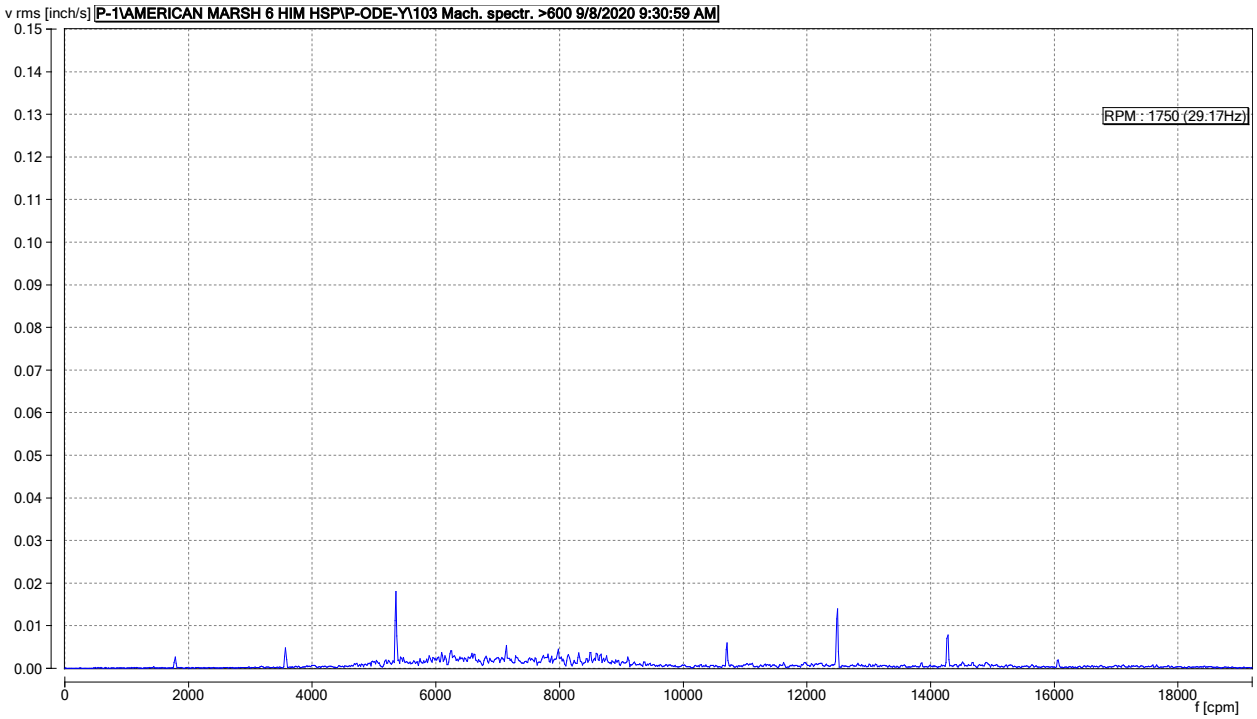


Figure 11: BP-1, P-ODE-Y. Maximum peaks are 0.018 in/sec rms at 5,351 cpm (3X run speed) and 0.014 in/sec rms at 12,491 cpm (7X run speed).

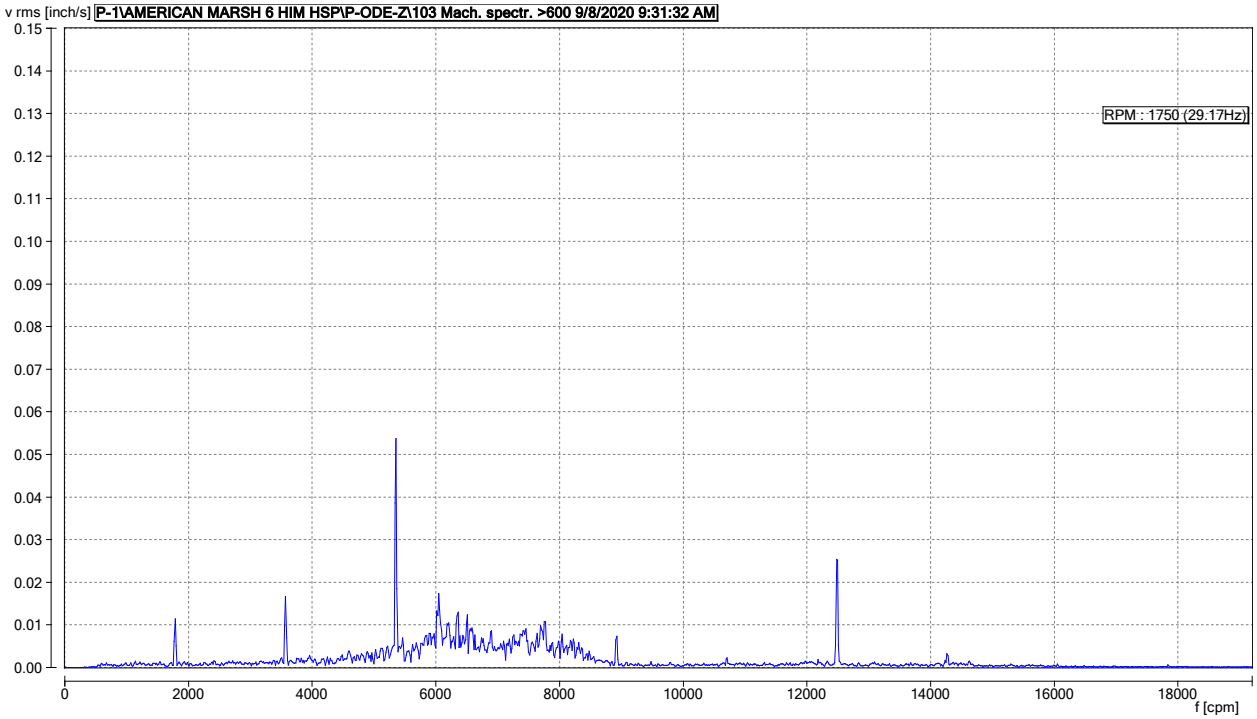


Figure 12: BP-1, P-ODE-Z. Maximum peaks are 0.054 in/sec rms at 5,351 cpm (3X run speed) and 0.025 in/sec rms at 12,488 cpm (7X run speed). Other peaks occur at 1X and 2X run speed.

The overall vibration readings recorded can be found below in Table 1. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 1: BP-1 Overal Vibration - Velocity (in/sec rms)

Time	8:33 AM	9:10 AM	9:25 AM
Speed	1,781	1,781	1,784
POR?	Yes	Yes	Yes
M-ODE-X	0.049	0.109	0.117
M-ODE-Y	0.029	0.047	0.133
M-ODE-Z	0.024	0.089	0.098
M-DE-X	0.058	0.131	0.133
M-DE-Y	0.039	0.132	0.124
P-DE-X	0.032	0.035	0.072
P-DE-Y	0.020	0.037	0.057
P-ODE-X	0.032	0.059	0.078
P-ODE-Y	0.019	0.027	0.045
P-ODE-Z	0.030	0.072	0.113

All vibration readings are below the HI limits.

TEST DISCUSSIONS

- Hydraulic Operation
  - It is difficult to make any conclusions on performance as the original catalog curve could not be located. An updated American-Marsh pump curve was used.
  - The pump performs well below the rated condition on the nameplate.
  - The customer labeled the base plate with 2,000 gpm as the rated flow, the maximum flow rate recorded during testing was 1,100 gpm.

- Electrical Operation
  - The maximum power recorded was 59 hp, well below the motor rated power of 75 hp

- Mechanical Operation
  - The maximum vibration is 0.133 in/sec rms, below the HI recommended limits
  - The vibration in the motor seems to be driven by looseness and the vibration in the pump seems to be driven by cavitation.

SUMMARY CONCLUSIONS

BP-1 motor vibration signatures show possible looseness which is generally caused by worn bearings. It is unclear how the pump is performing as the catalog curve could not be found but the nameplate shows 1,400 gpm at 175 ft and, according to the test, the trend line is significantly lower than this. The rest of the pump appears to be in good condition with no significant vibration. It is recommended the motor be pulled and inspected and the pump be disassembled to determine the cause for the significant loss in performance.

TEST RESULTS: BP-2

TEST RESULTS

The composite curve in Figure 13 below shows field data points plotted against the catalog curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Measured using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	American Marsh	**Rated Capacity**	[gpm]	1,400	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	175	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	HIM, Size 6	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,750	**Witnessed By**	
Tag Number	P-2	**Serial Number**	45916	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

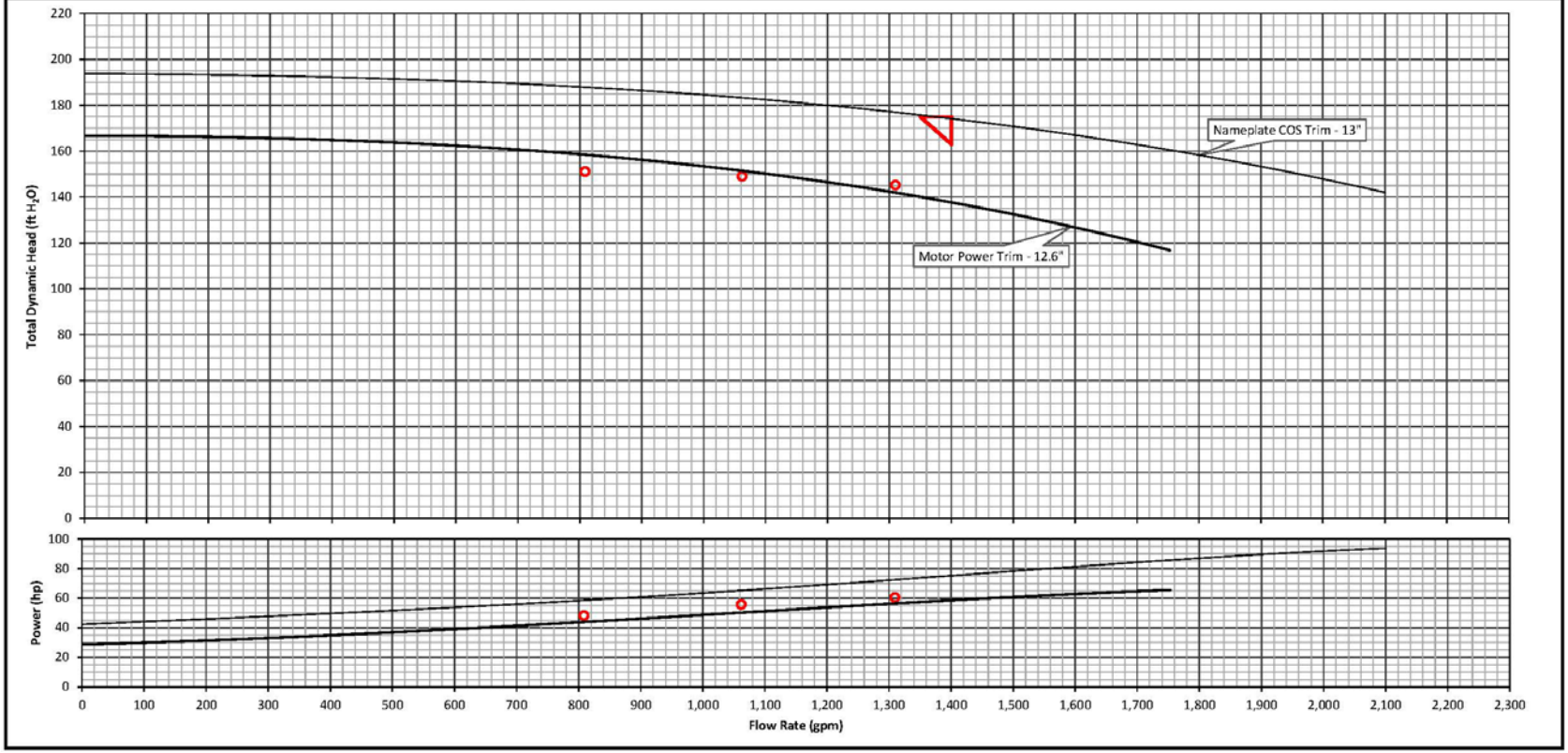


Figure 13: BP-2 Field Test

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-2. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the factory test curves at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below in Figure 14 to Figure 23 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

The spectrums on the motor show pole pass frequency sidebands around the 2X electrical frequency. This is generally a sign of cracked or broken rotor bars.

The spectrums on the pump show peaks at 7X run speed which is very likely the vane pass freuqenecy.

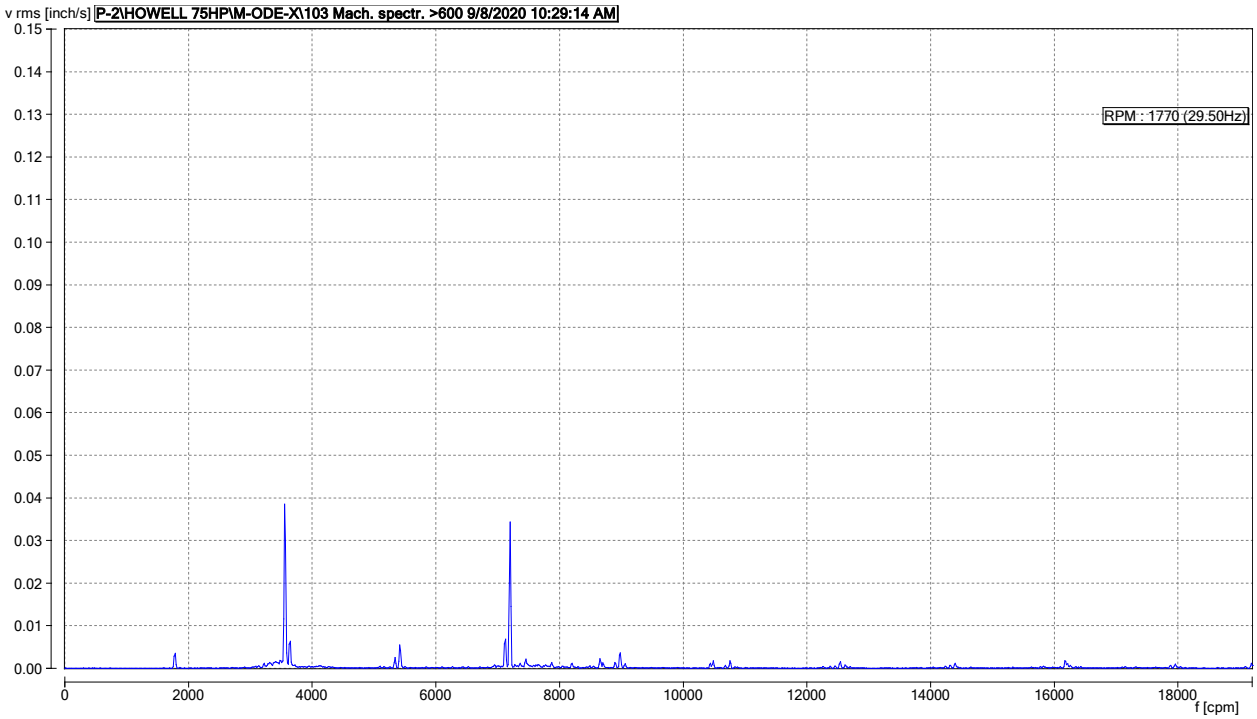


Figure 14: BP-2, M-ODE-X. Maximum peaks are 0.038 in/sec rms at 3,559 cpm (2X run speed) and 0.034 in/sec rms at 7,196 cpm (2X electrical), each with sidebands at 173 cpm. The 2X run speed peak has sidebands at 78 cpm which is a pole pass frequency.

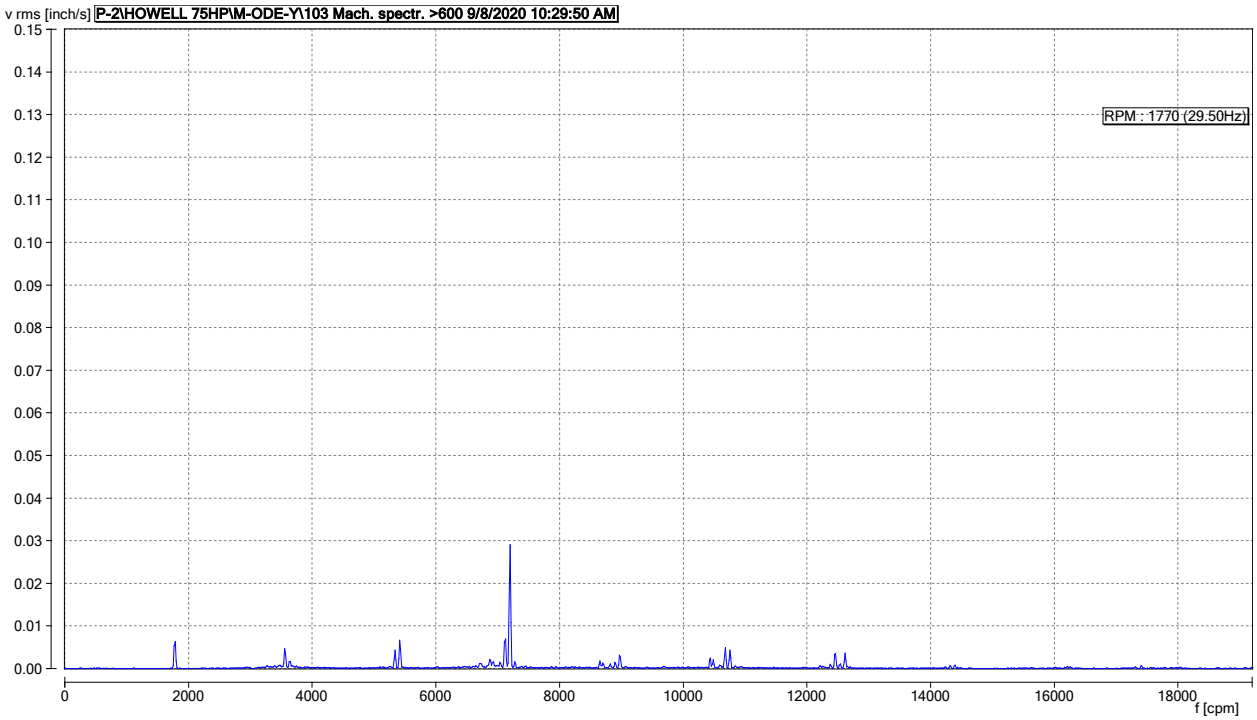


Figure 15: BP-2, M-ODE-Y. Maximum peak is 0.029 in/sec rms at 7,196 cpm (2X electrical) with sidebands at 79 cpm which is the pole pass frequency; the smaller peaks have similar sidebands.

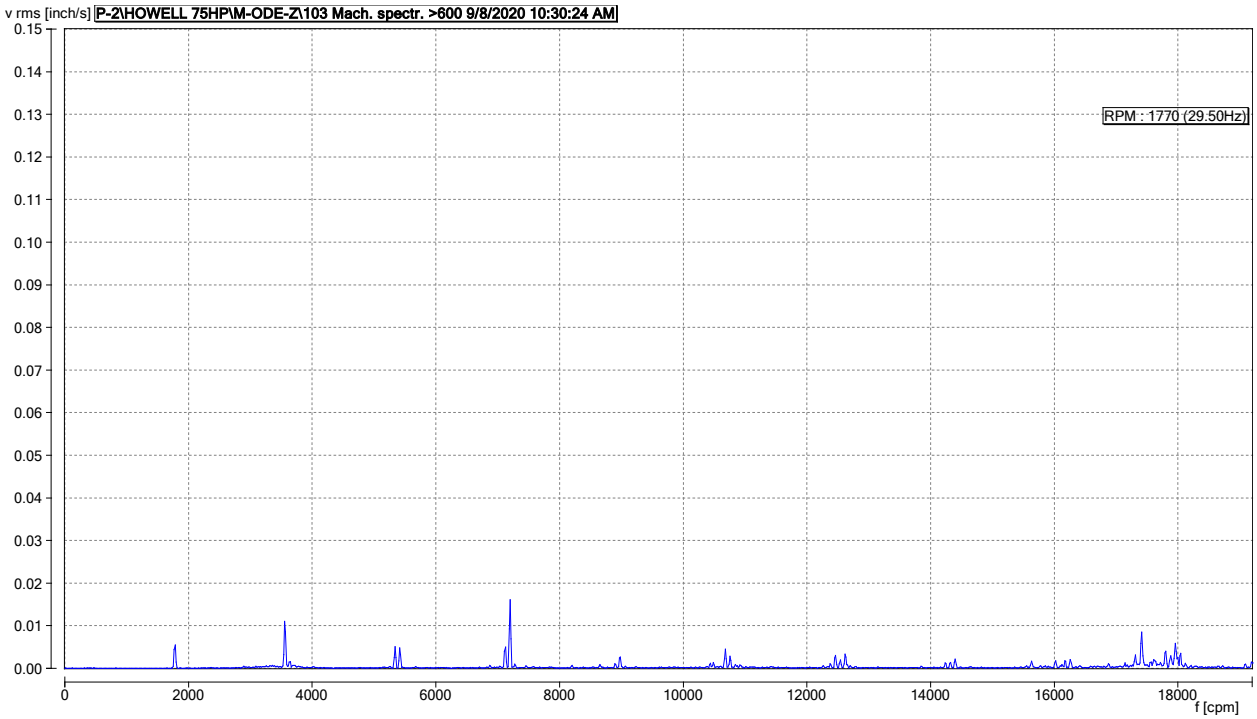


Figure 16: BP-2, M-ODE-Z. Maximum peak is 0.016 in/sec rms at 7,200 cpm (2X electrical). Each peak in the spectrum has sidebands at 79 cpm which is a pole pass frequency.

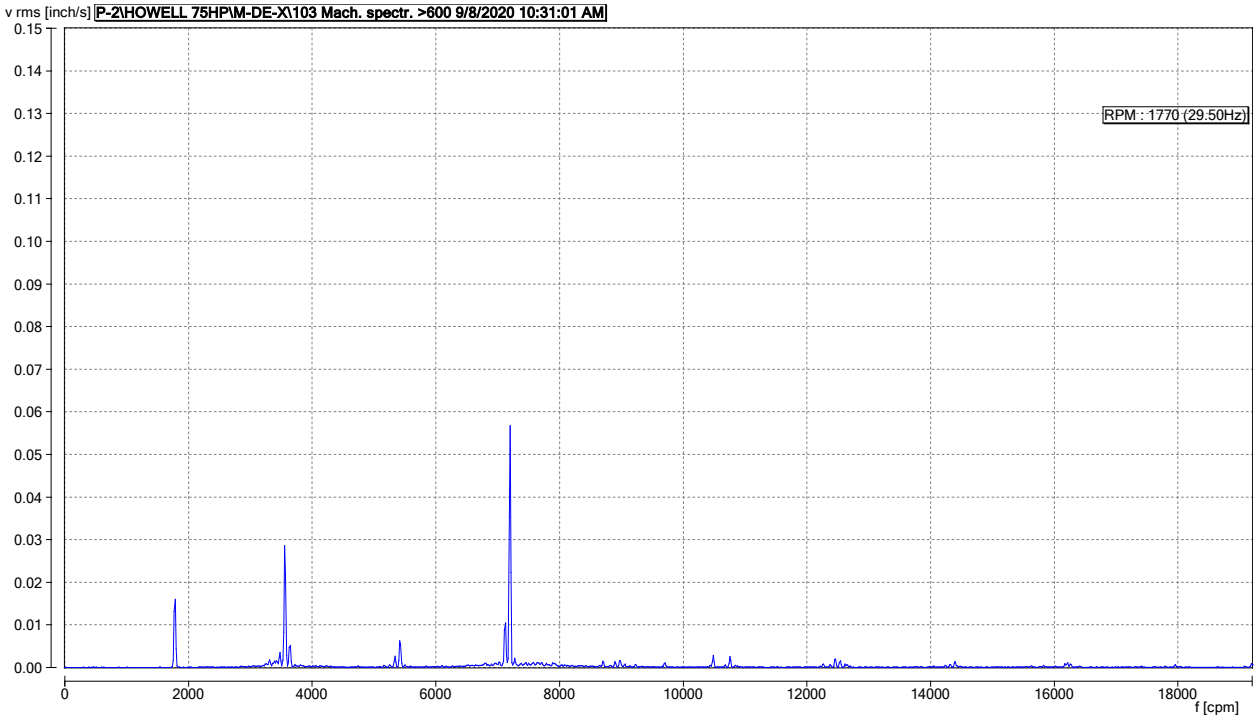


Figure 17: BP-2, M-DE-X. Maximum peaks are 0.057 in/sec rms at 7,196 cpm (2X electrical), 0.029 in/sec rms at 3,559 cpm (2X run speed), and 0.016 in/sec rms at 1,778 cpm (1X run speed). Each peak has a sideband of 79 cpm which is a pole pass frequency.

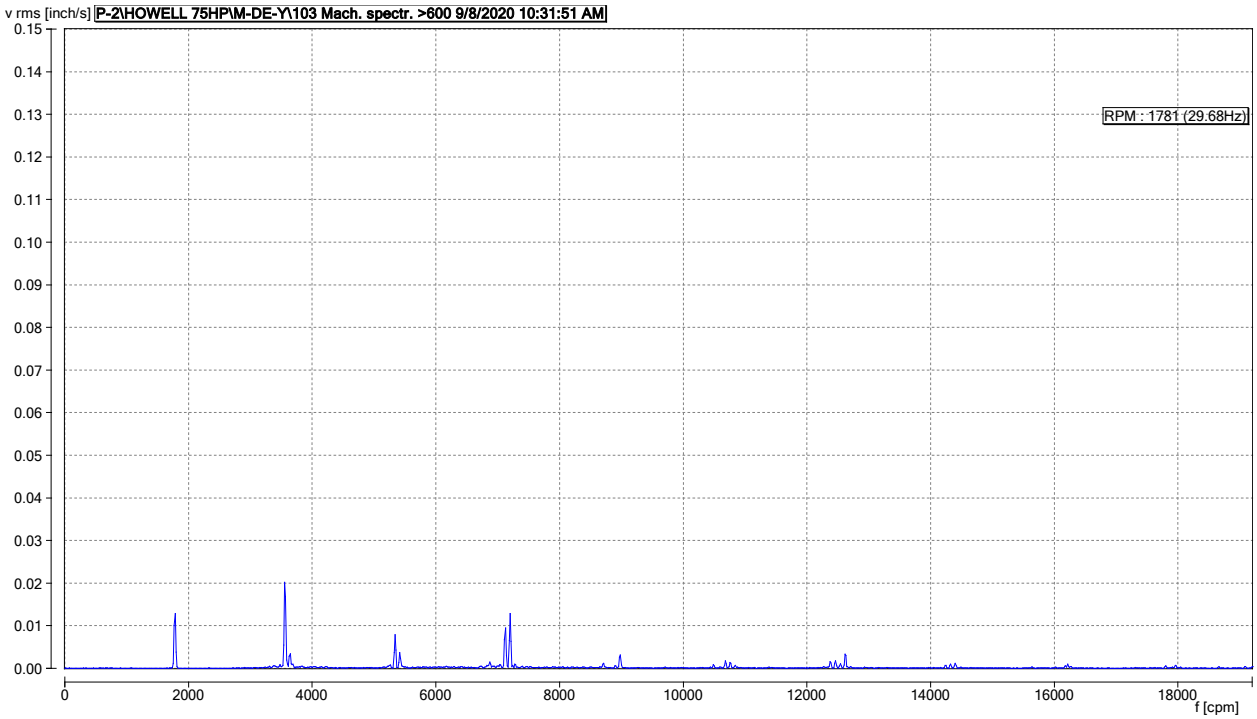


Figure 18: BP-2, M-DE-Y. Maximum peaks are 0.020 in/sec rms at 1,789 cpm (1X run speed), 0.013 in/sec rms at 1,781 cpm (1X run speed), and 0.013 in/sec rms at 7,200 cpm (2X electrical).

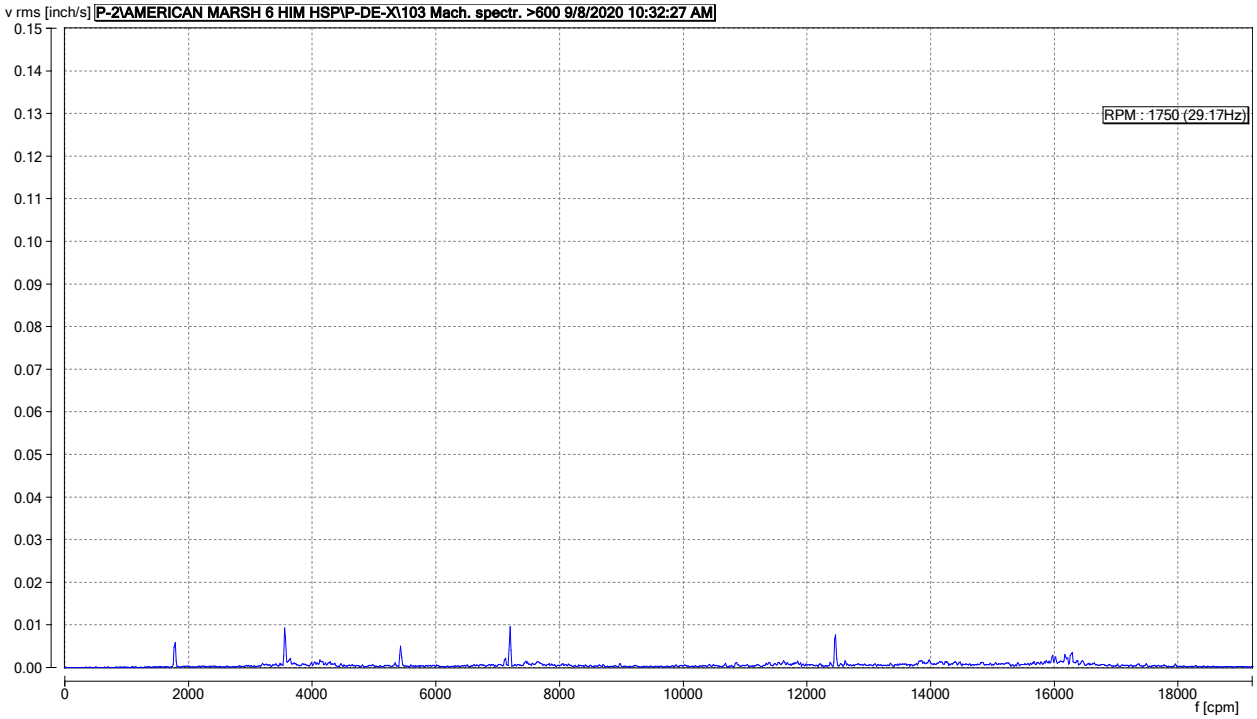


Figure 19: BP-2, P-DE-X. All peaks are very low.

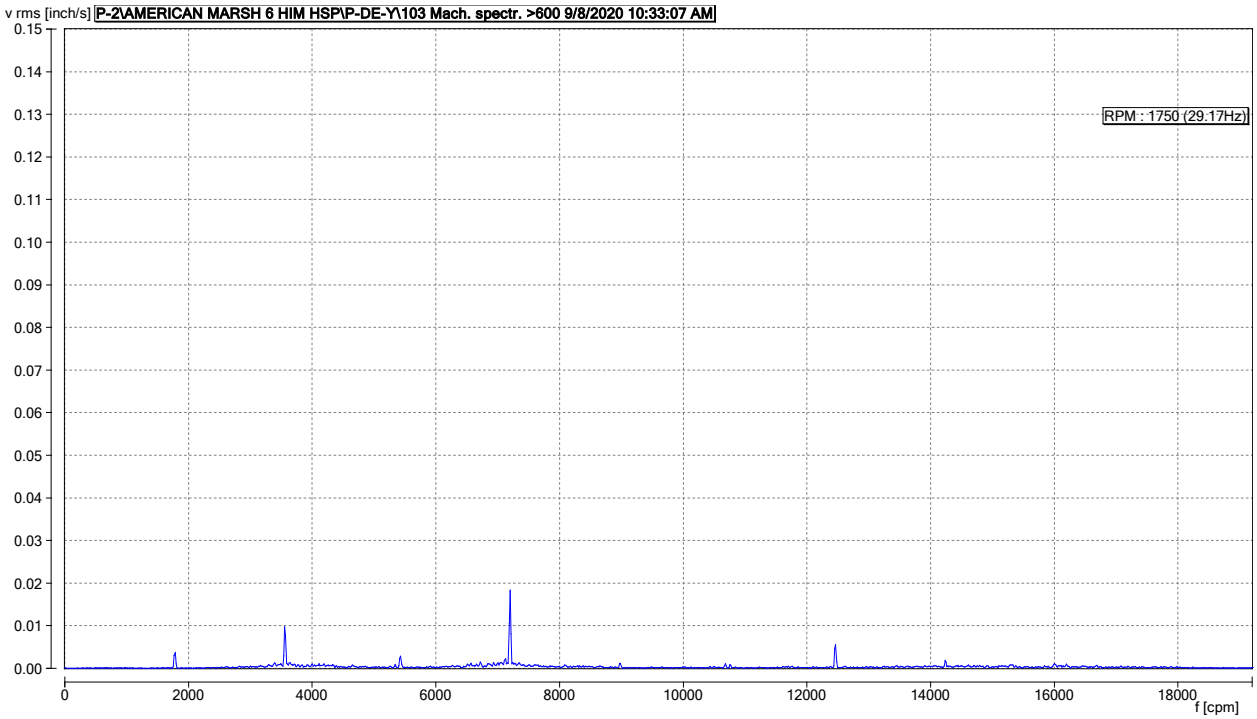


Figure 20: BP-2, P-DE-Y. Maximum peak is 0.018 in/sec rms at 7,200 cpm (2X electrical).

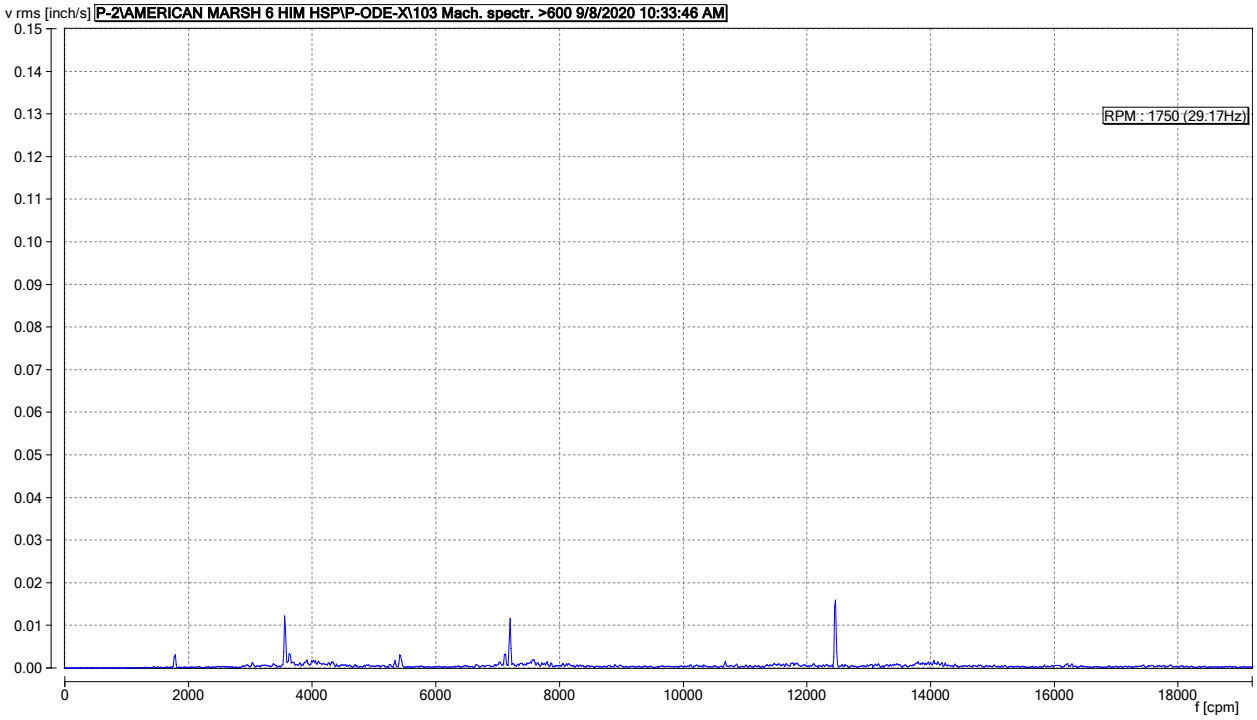


Figure 21: BP-2, P-ODE-X. Maximum peak is 0.016 in/sec rms at 12,457 cpm (7X run speed).

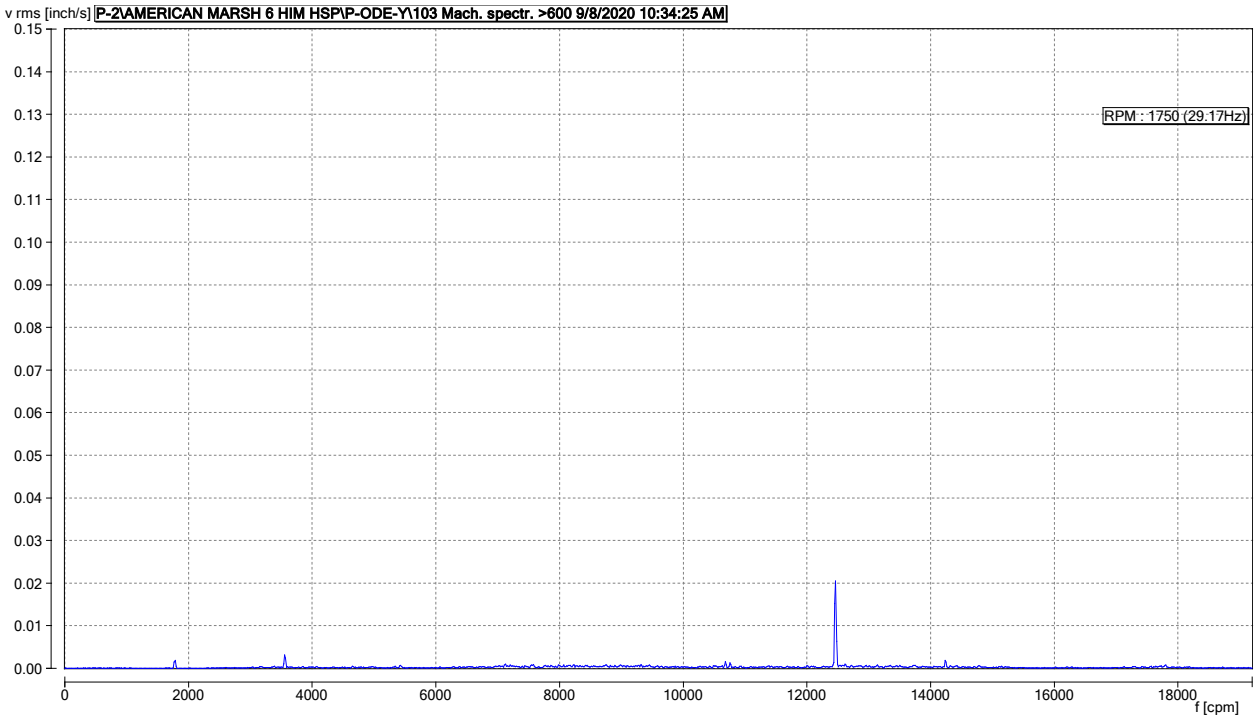


Figure 22: BP-2, P-ODE-Y. Maximum peak is 0.020 in/sec rms at 12,461 cpm (7X run speed).

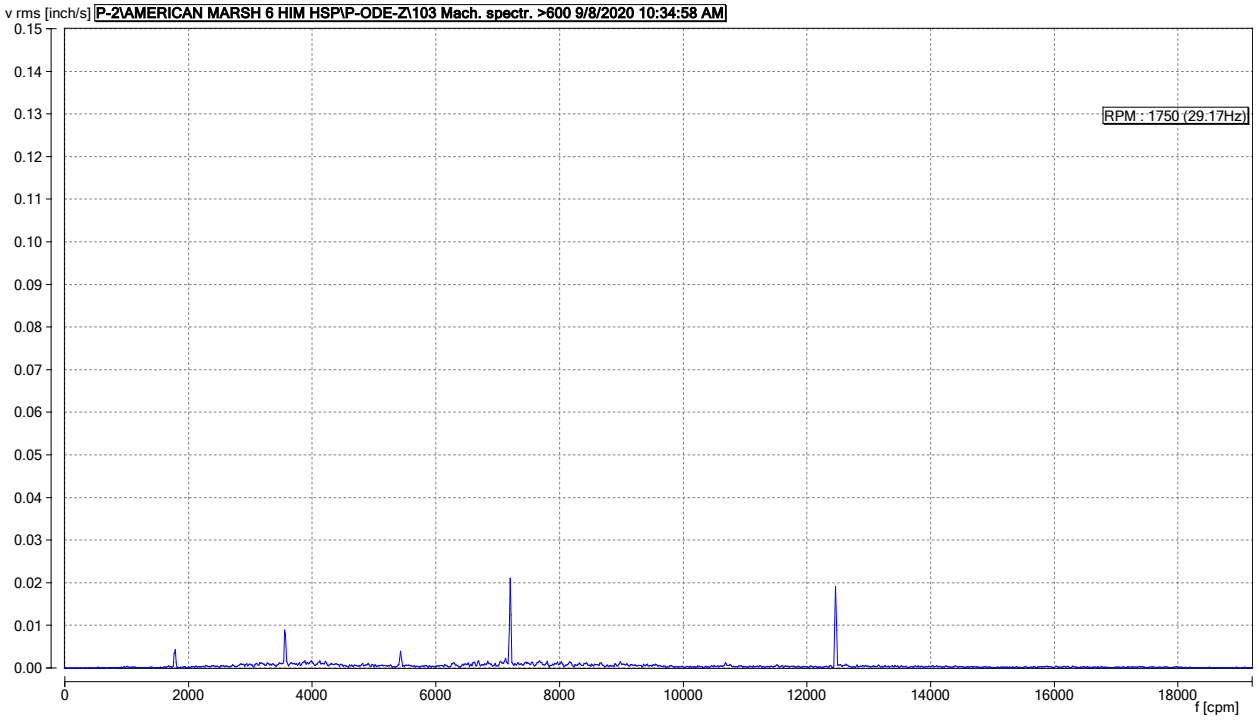


Figure 23: BP-2, P-ODE-Z. Maximum peaks are 0.021 in/sec rms at 7,200 cpm (2X electrical) and 0.019 in/sec rms at 12,465 cpm (7X run speed).

The overall vibration readings recorded can be found below in Table 2. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 2: BP-2 Overal Vibration - Velocity (in/sec rms)

Time	10:00 AM	10:12 AM	10:26 AM
Speed	1,778	1,783	1780
POR?	Yes	Yes	Yes
M-ODE-X	0.054	0.058	0.052
M-ODE-Y	0.043	0.039	0.034
M-ODE-Z	0.030	0.028	0.032
M-DE-X	0.064	0.063	0.072
M-DE-Y	0.036	0.037	0.035
P-DE-X	0.036	0.041	0.029
P-DE-Y	0.018	0.032	0.027
P-ODE-X	0.040	0.045	0.034
P-ODE-Y	0.023	0.028	0.025
P-ODE-Z	0.036	0.050	0.039

All of the overall vibration readings are very low.

TEST DISCUSSIONS

- Hydraulic Operation
  - It is difficult to make any conclusions on performance as the original catalog curve could not be located. An updated American-Marsh pump curve was used.
  - The pump performs well below the rated condition on the nameplate.
  - The customer labeled the base plate with 2,000 gpm as the rated flow, the maximum flow rate recorded during testing was 1,310 gpm.

- Electrical Operation
  - The maximum power recorded was 62 hp, well below the motor rated power of 75 hp.

- Mechanical Operation
  - The maximum vibration is 0.072 in/sec rms, well below the HI recommended limits.
  - The motor vibration seems to be driven by a potential electrical fault. The pump vibration appears to be caused by vane pass.

SUMMARY CONCLUSIONS

BP-2 motor vibration signatures show a potential electrical fault though it does not seem to be too significant at this point. It is unclear how the pump is performing as the catalog curve could not be found but the nameplate shows 1,400 gpm at 175 ft and, according to the test, the trend line is significantly lower than this. The rest of the pump appears to be in good condition with no significant vibration. It is recommended the motor be pulled and inspected and the pump be disassembled to determine the cause for the significant loss in performance.

TEST RESULTS: BP-3

TEST RESULTS

The composite curve in Figure 24 below shows field data points plotted against the factory test curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Measured using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	Fairbanks-Morse	**Rated Capacity**	[gpm]	Unknownn	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	Unknownn	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	1823, 6"	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,775	**Witnessed By**	
Tag Number	P-3	**Serial Number**	Unknown	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

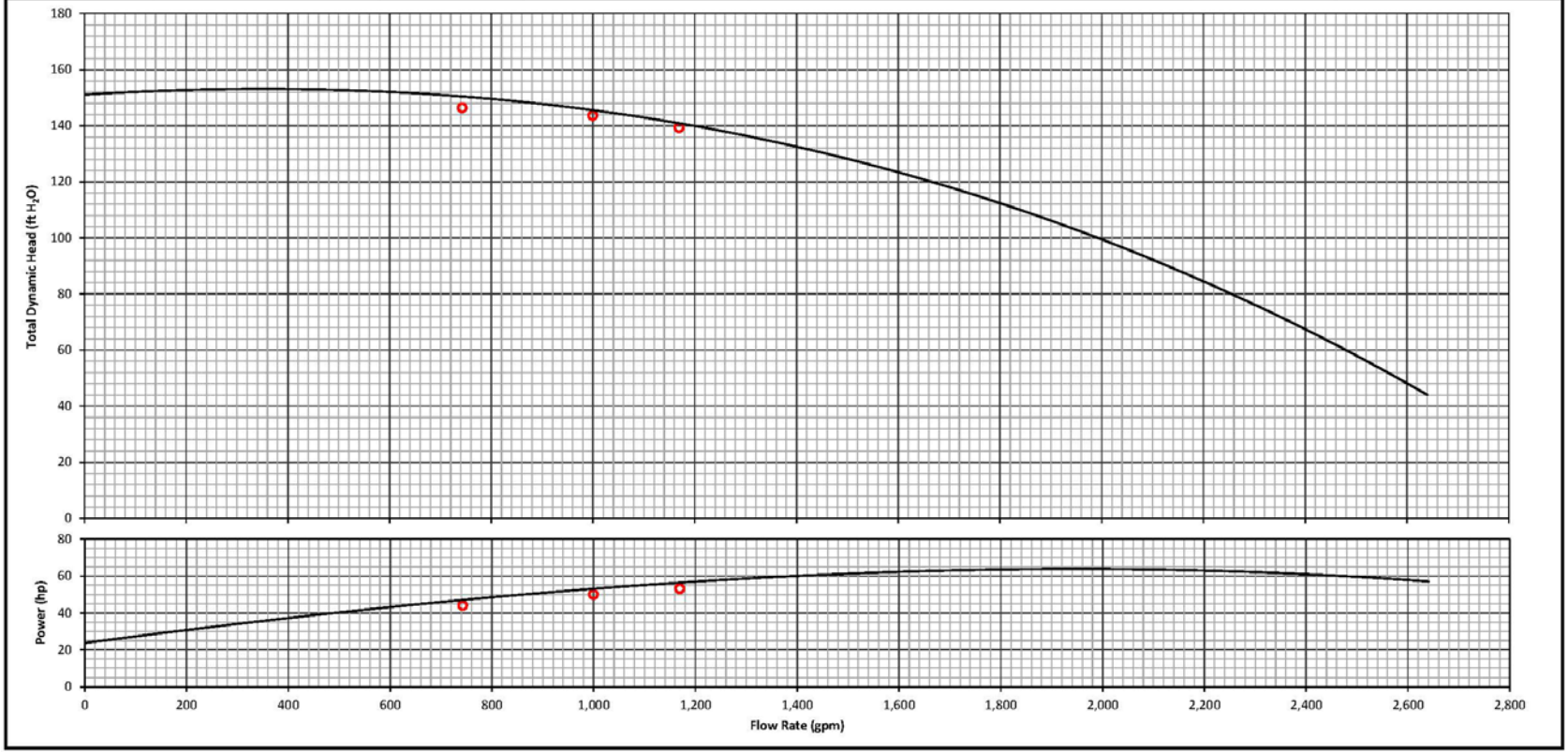


Figure 24: BP-3 Field Test

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-3. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the factory test curves at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below Figure 25 to Figure 34 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

The spectrums from the motor have a 2X electrical frequency and sidebands at 55 cpm. It is uncertain what the cuase is for these sidebands but possible a bearing fault. Currenlty the vibration is low and not of too much concern.

The spectrums for the pump show a possible vane pass at 6X run speed, common on split case pumps, and a possible minor misalignment as shown by the 1X and 2X run speed peaks.

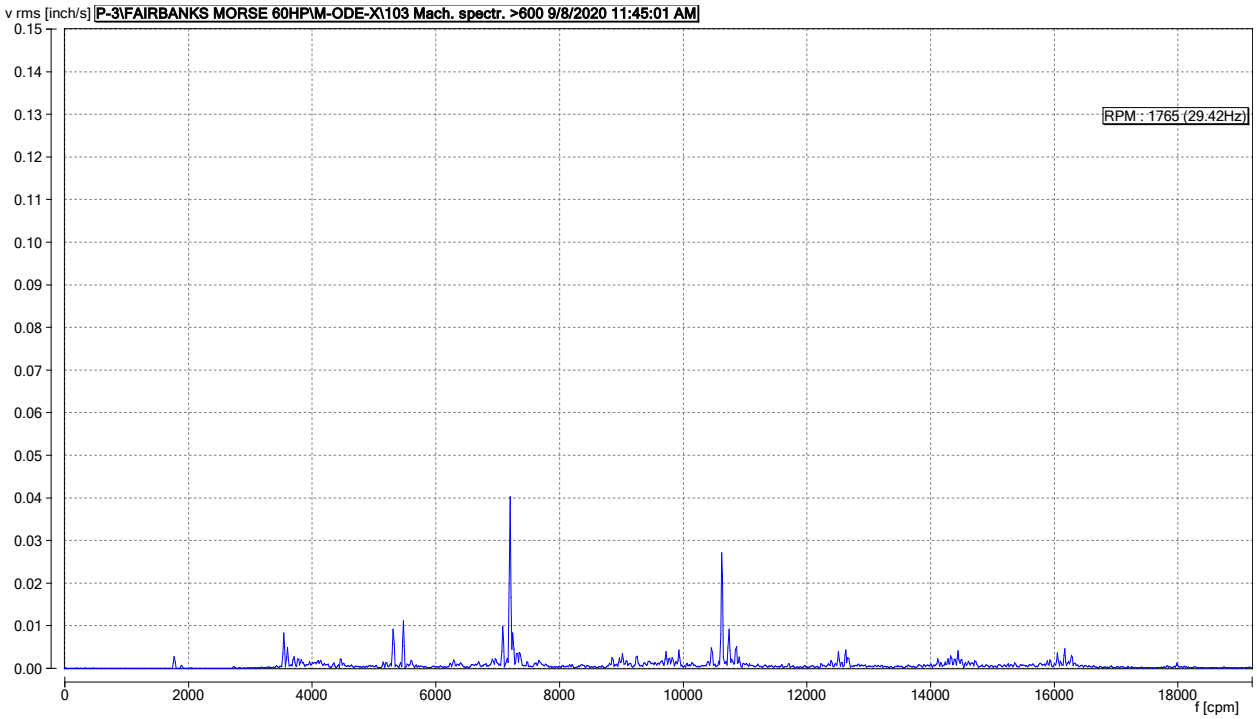


Figure 25: BP-3, M-ODE-X. Maximum peaks are 0.040 in/sec rms at 7,196 cpm (2X electrical) and 0.027 in/sec rms at 10,624 cpm (6X run speed). All peaks have sidebands at 55 cpm.

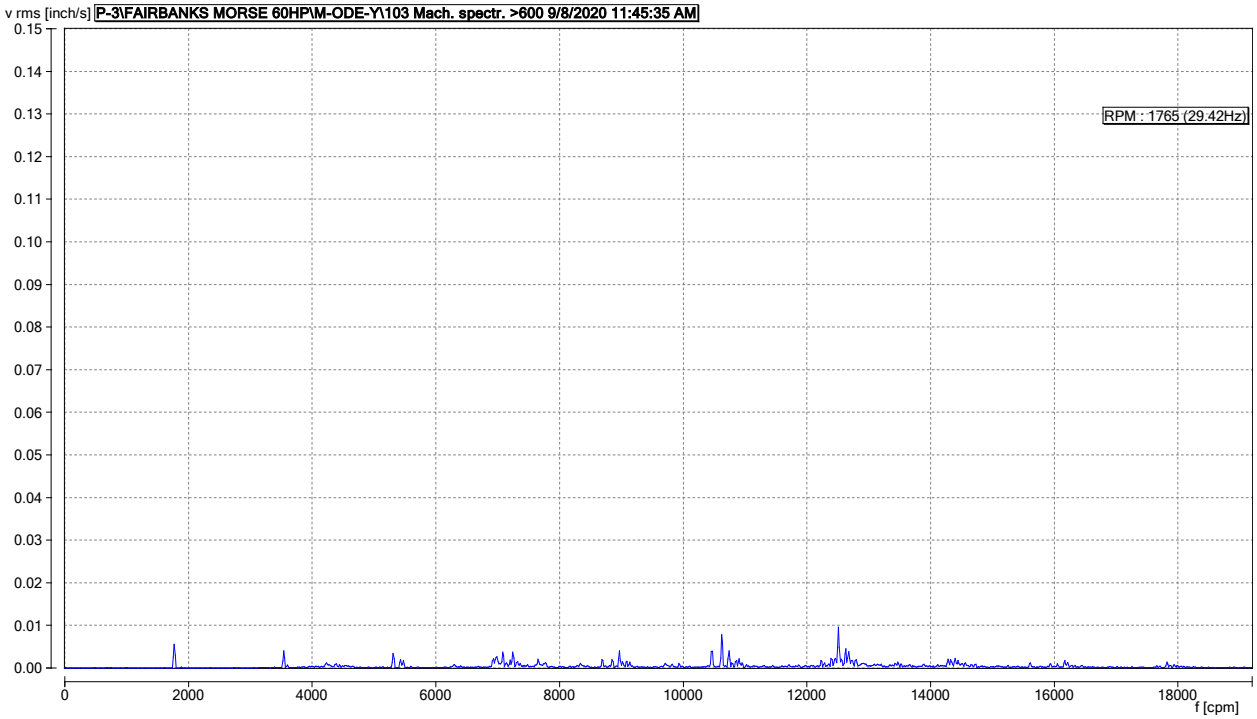


Figure 26: BP-3, M-ODE-Y. All peaks are low.

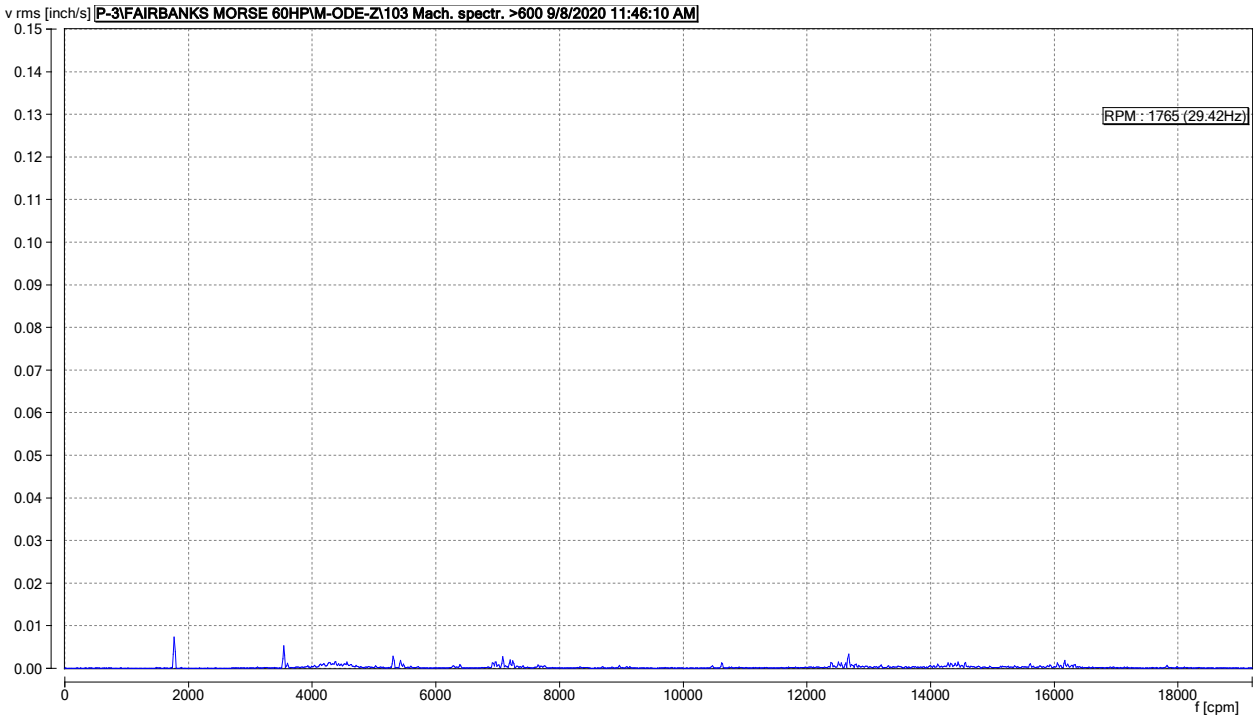


Figure 27: BP-3, M-ODE-Z. All peaks are low.

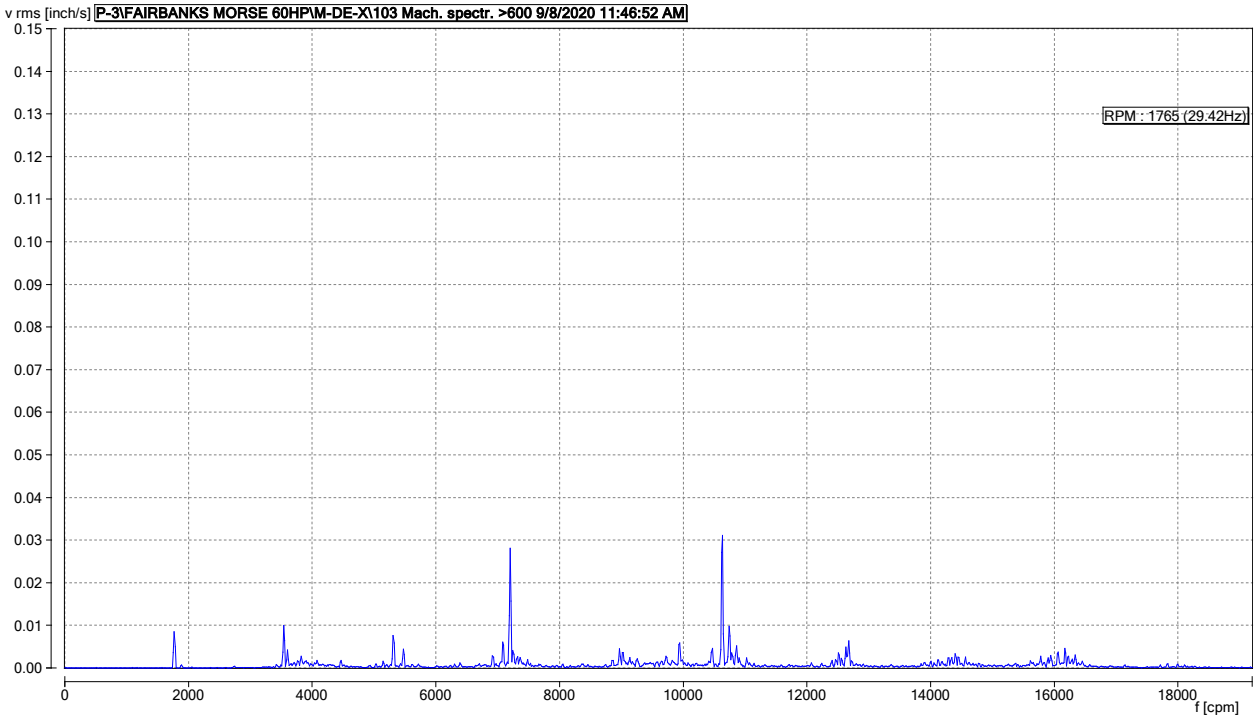


Figure 28: BP-3, M-DE-X. Maximum peaks are 0.031 in/sec rms at 10,627 cpm (6X run speed) and 0.028 in/sec rms at 7,200 cpm (2X electrical). Each peak has sidebands around 55 cpm.

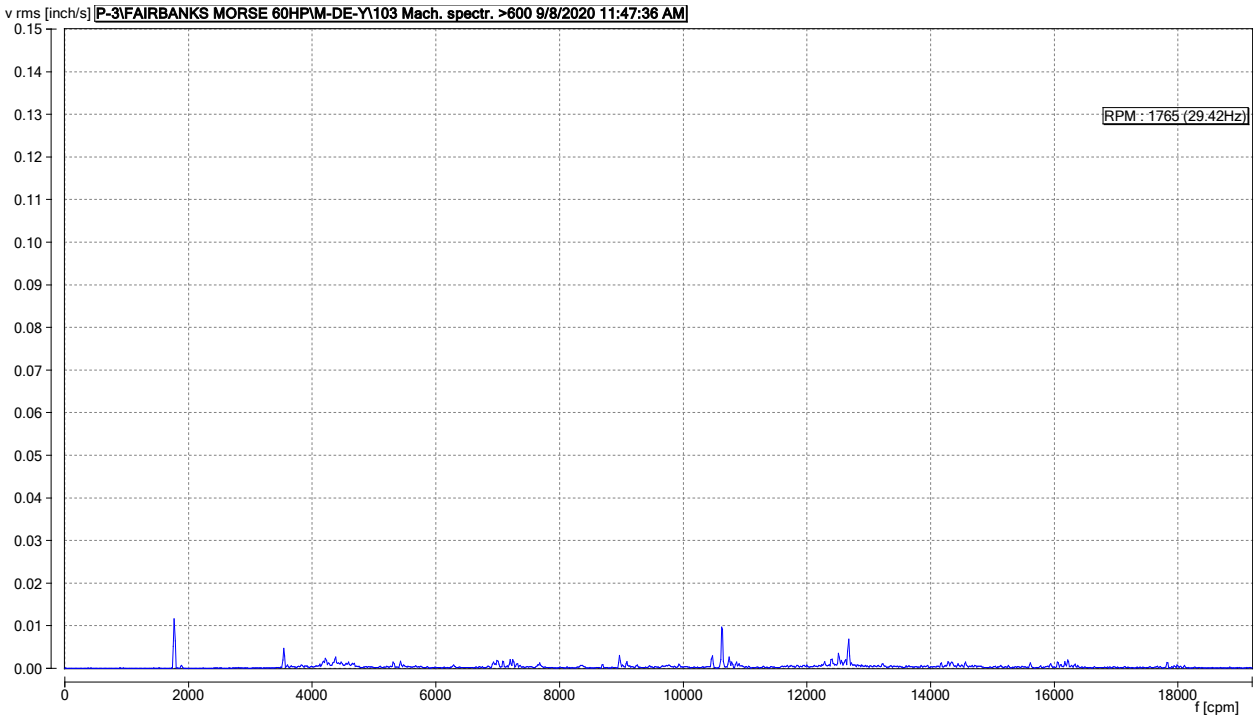


Figure 29: BP-3, M-DE-Y. All peaks are very low.

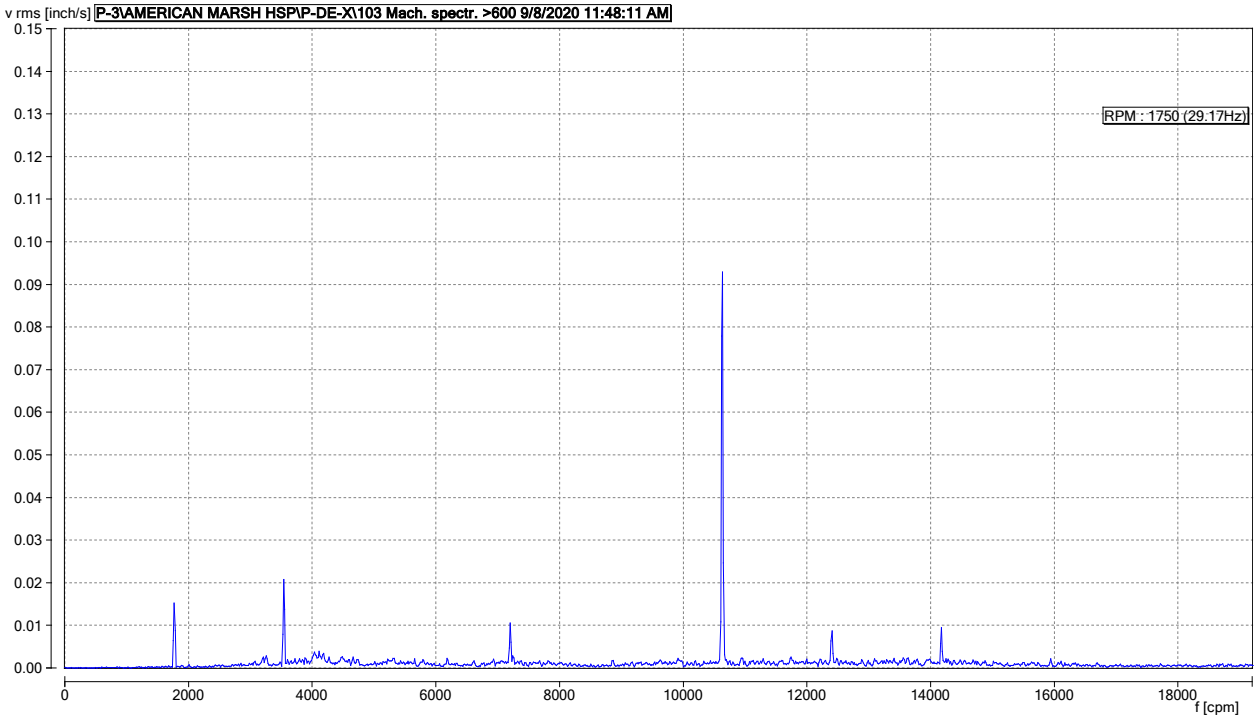


Figure 30: BP-3, P-DE-X. Maximum peak is 0.093 in/sec rms at 10,627 cpm (6X run speed).

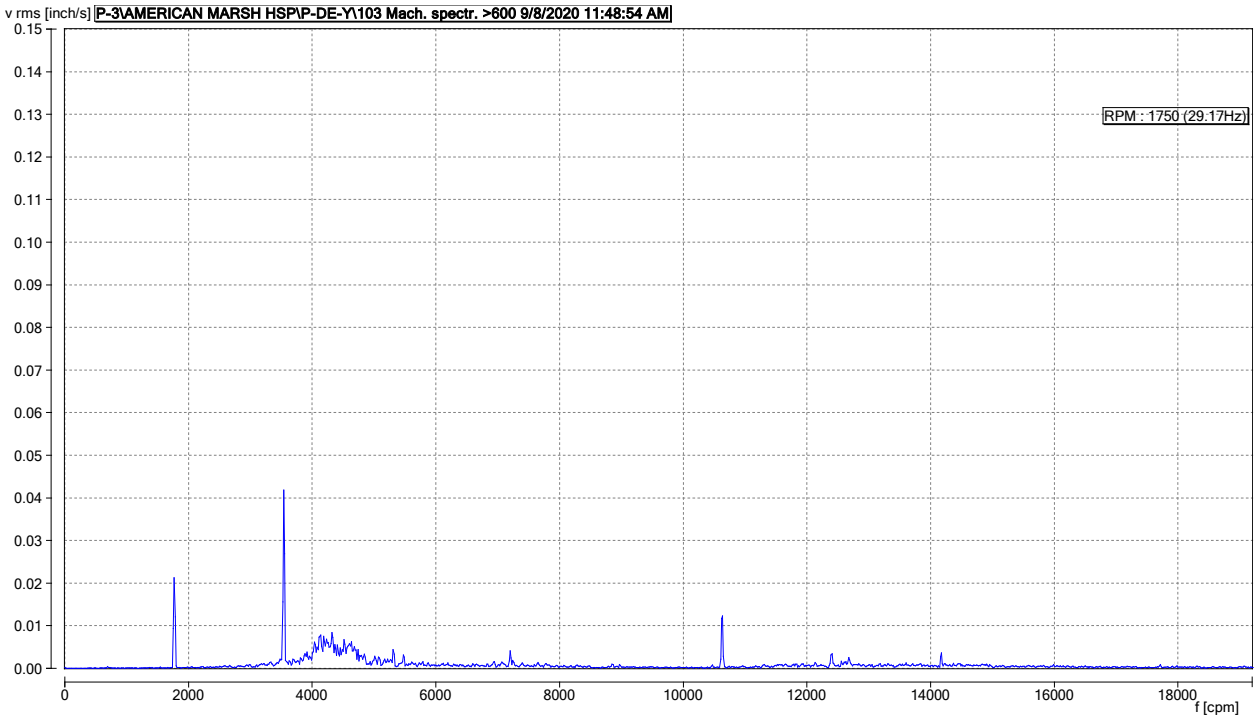


Figure 31: BP-3, P-DE-Y. Maximum peaks are 0.042 in/sec rms at 3,543 cpm (2X run speed) and 0.021 in/sec rms at 1,770 cpm (1X run speed).

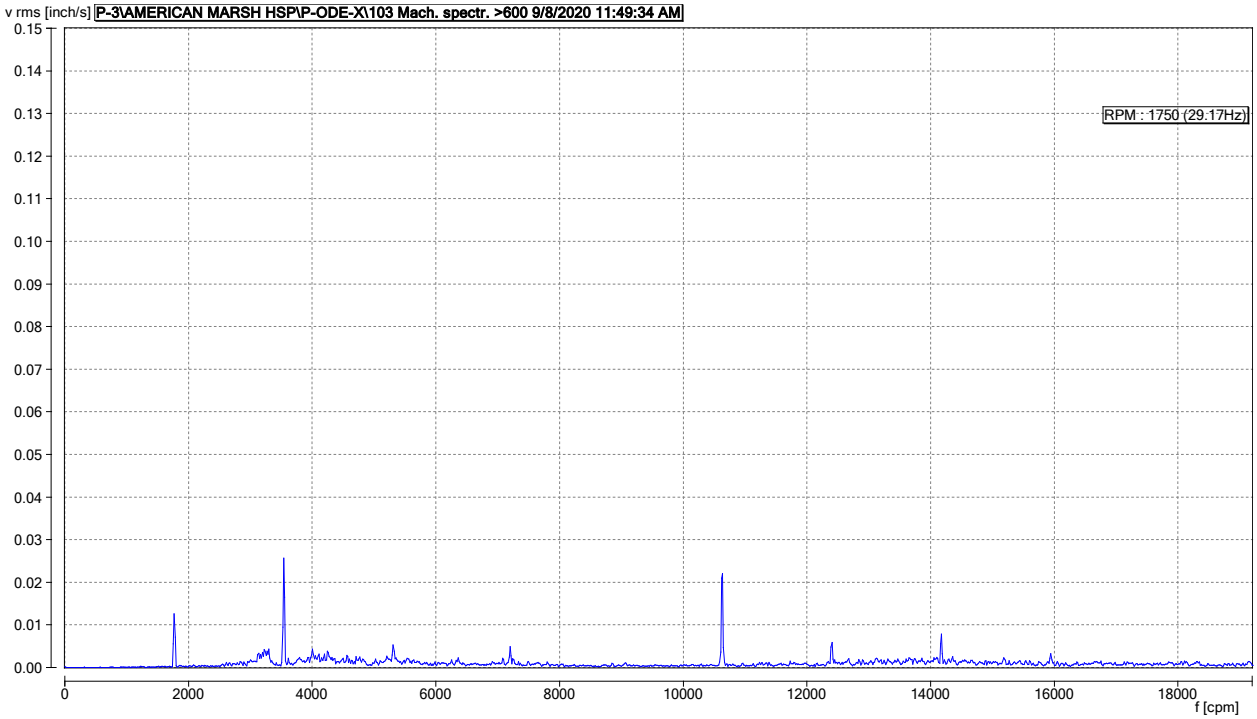


Figure 32: BP-3, P-ODE-X. Maximum peaks are 0.026 in/sec rms at 3,543 cpm (2X run speed) and 0.022 in/sec rms at 10,627 cpm (6X run speed).

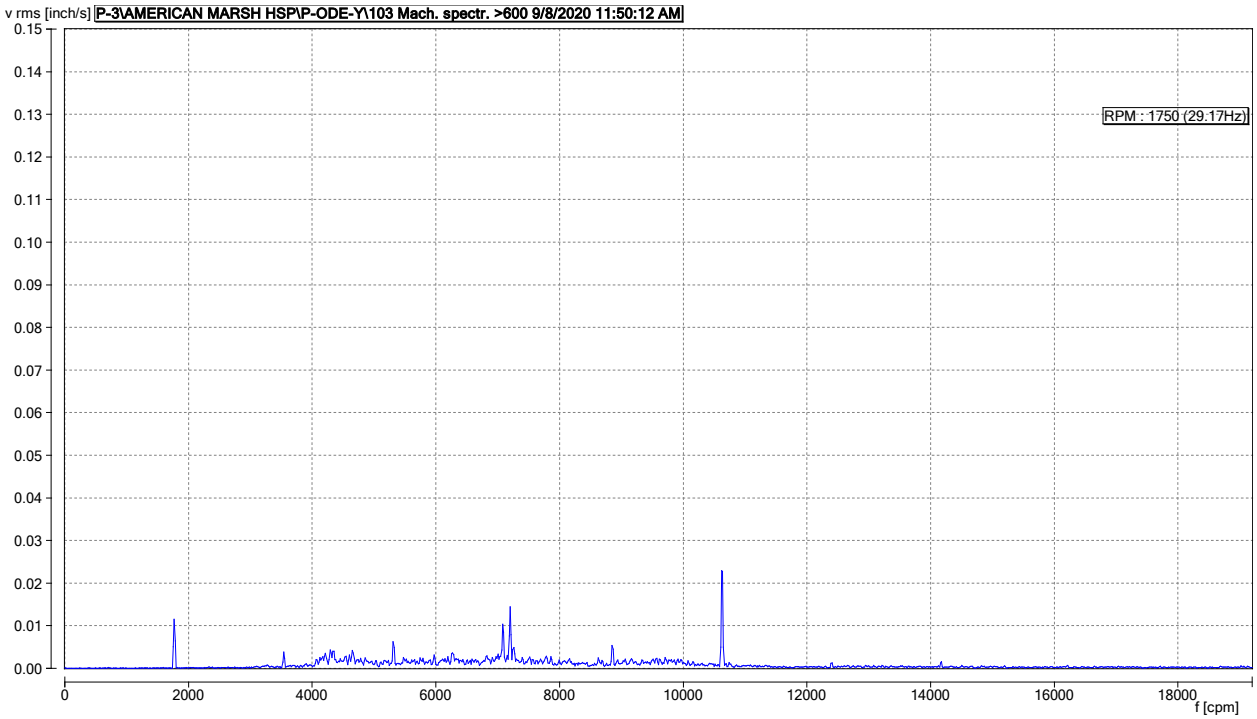


Figure 33: BP-3, P-ODE-Y. Maximum peak is 0.023 in/sec rms at 10,627 cpm (6X run speed).

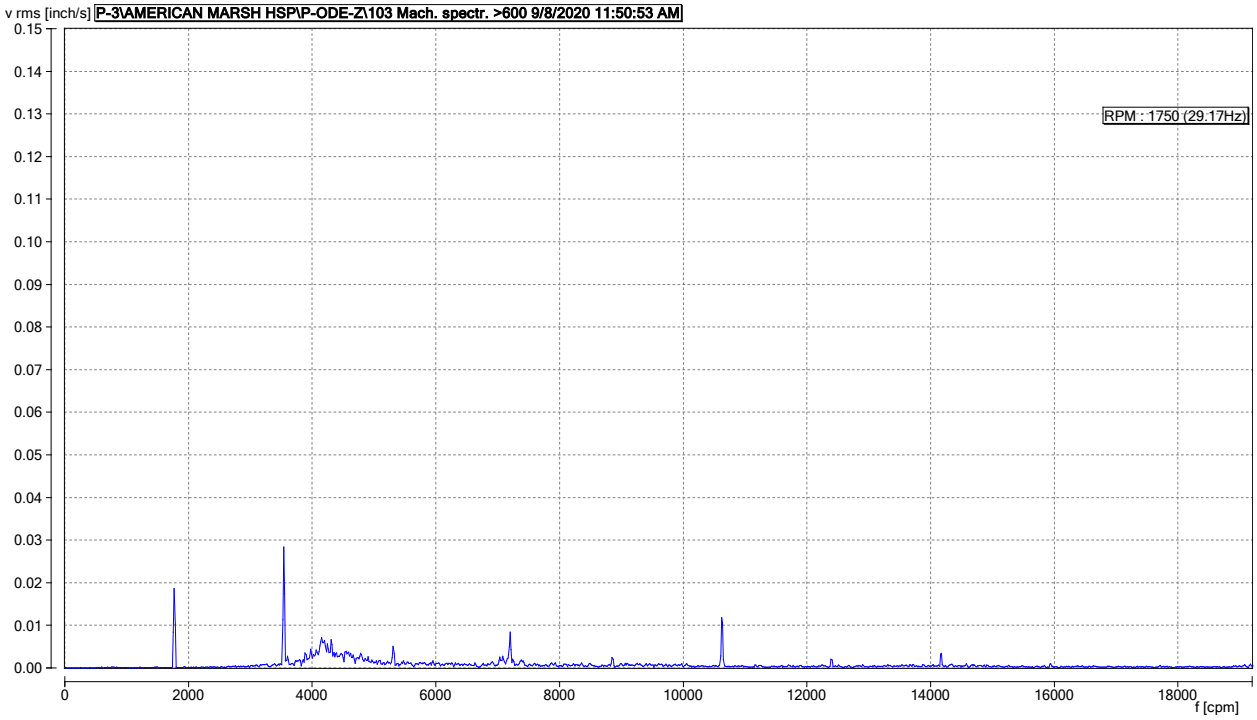


Figure 34: BP-3, P-ODE-Z. Maximum peaks are 0.028 in/sec rms at 3,543 cpm (2X run speed) and 0.019 in/sec rms at 1,770 cpm (1X run speed).

The overall vibration readings recorded can be found below in Table 3. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 3: BP-3 Overal Vibration - Velocity (in/sec rms)

Time	11:01 AM	11:25 AM	11:45 AM
Speed	1,766	1,767	1,771
POR?	Yes	Yes	Yes
M-ODE-X	0.017	0.018	0.018
M-ODE-Y	0.056	0.060	0.060
M-ODE-Z	0.025	0.024	0.028
M-DE-X	0.050	0.055	0.059
M-DE-Y	0.021	0.023	0.025
P-DE-X	0.062	0.087	0.116
P-DE-Y	0.044	0.056	0.067
P-ODE-X	0.045	0.051	0.060
P-ODE-Y	0.040	0.042	0.052
P-ODE-Z	0.041	0.043	0.056

All overall vibration readings are low.

TEST DISCUSSIONS

- Hydraulic Operation
  - The pump model and therefore catalog curve could not be located. Using the test data points, the nearest pump curve was used.
  - It is likely this pump is performing well but it is impossible to tell for certain without the actual pump curve.

- Electrical Operation
  - The maximum power recorded was 52 hp, well below the motor rated power of 60 hp
  - If the pump curve selected is the real curve, then the motor horsepower will be exceeded when the pump exceeds 1,400 gpm.

- Mechanical Operation
  - The maximum is 0.116 in/sec rms, below the HI recommended limits.
  - The driving motor vibration appears to be a slight electrical fault with possible sidebands at a bearing frequency.
  - The driving pump vibration appears to be a slight misalignment and vane pass.

SUMMARY CONCLUSIONS

BP-3 pump appears to be operating close to the catalog curve if the curve selected is correct and the pump is operating with low vibration. The motor appears to have a slight electrical fault with a potential bearing fault but nothing to be too concerned about and is operating well. If the pump catalog curve is correct, the motor horsepower will be exceeded if the flow rate exceed 1,400 gpm.

TEST RESULTS: BP-4

TEST RESULTS

The composite curve in Figure 35 below shows field data points plotted against the factory test curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Measured using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

Smith Pump Company, Inc.
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FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	ITT A-C	**Rated Capacity**	[gpm]	1,500	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	132	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	8100, 8x6x12L, 12.8" trim	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,775	**Witnessed By**	
Tag Number	P-4	**Serial Number**	1-74417-01-1	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

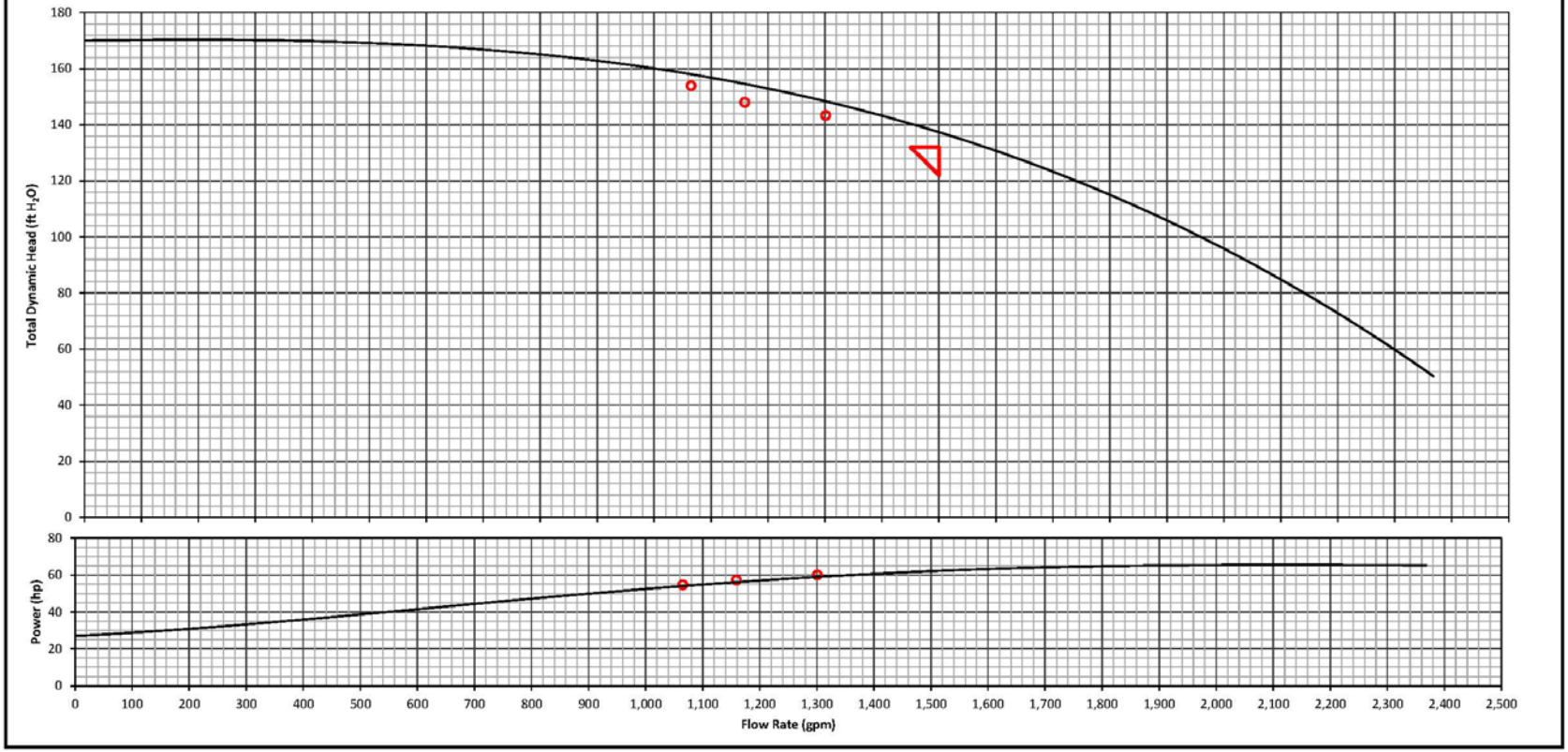

Figure 35: BP-4 Field Test

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-4. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the factory test curves at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below in Figure 36 to Figure 45 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

The spectrums from the motor have peaks at 2X run speed and 2X electrical. The 2X run speed is likely caused by minor misalignment. The 2X electrical is low without any sidebands and is likely not an issue .

The spectrums for the pump show a possible vane pass at 7X run speed, common on split case pumps.

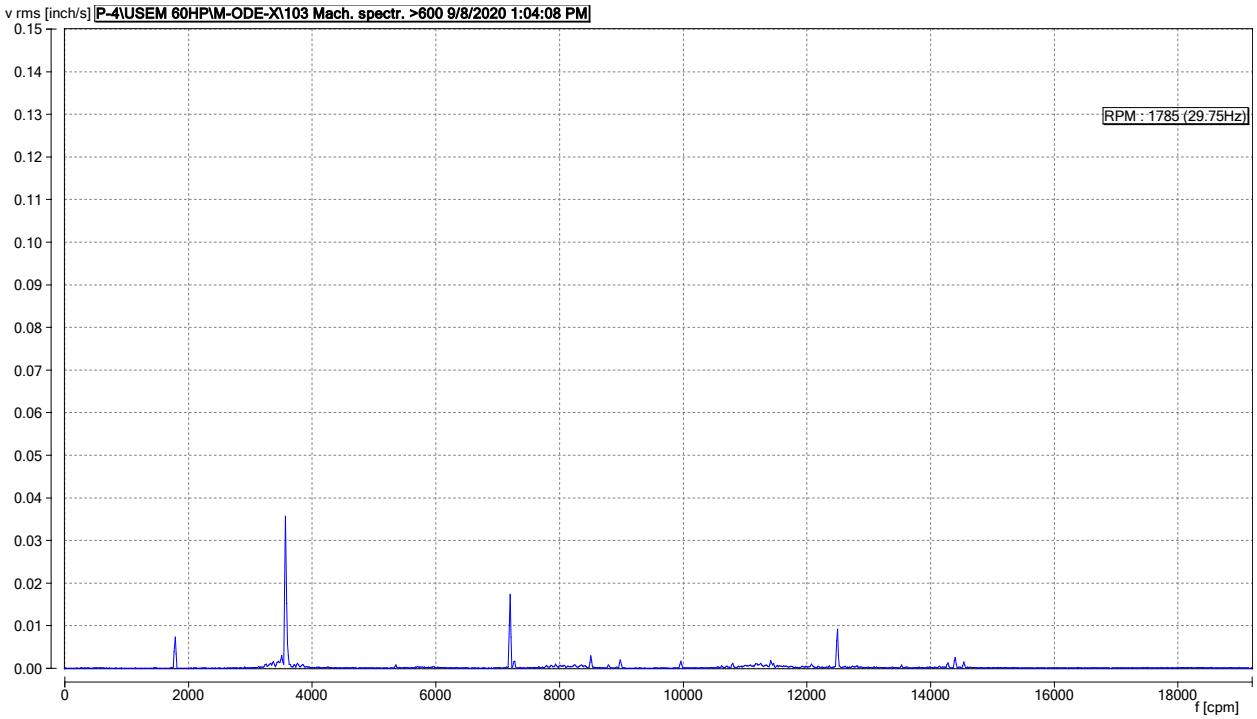

Figure 36: BP-4, M-ODE-X. Maximum peaks are 0.036 in/sec rms at 3,570 cpm (2X run speed) and 0.017 in/sec rms at 7,200 cpm (2X electrical).

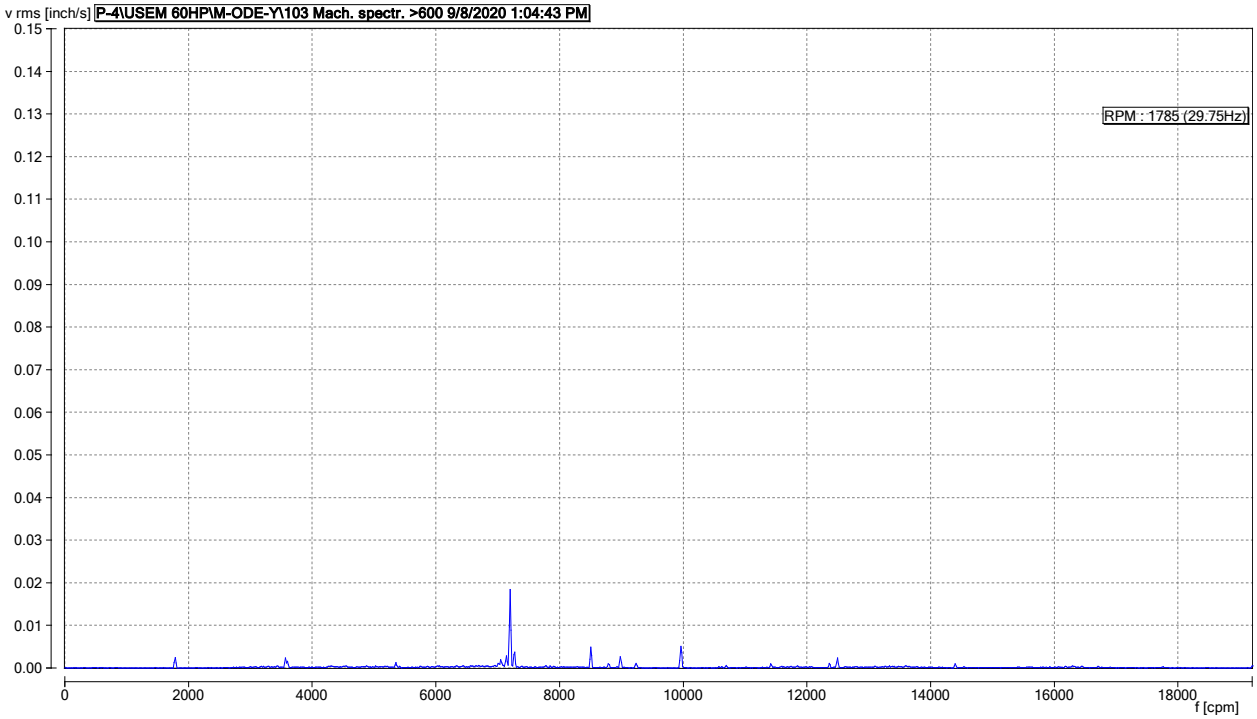

Figure 37: BP-4, M-ODE-Y. Maximum peak is 0.018 in/sec rms at 7,200 cpm (2X electrical).

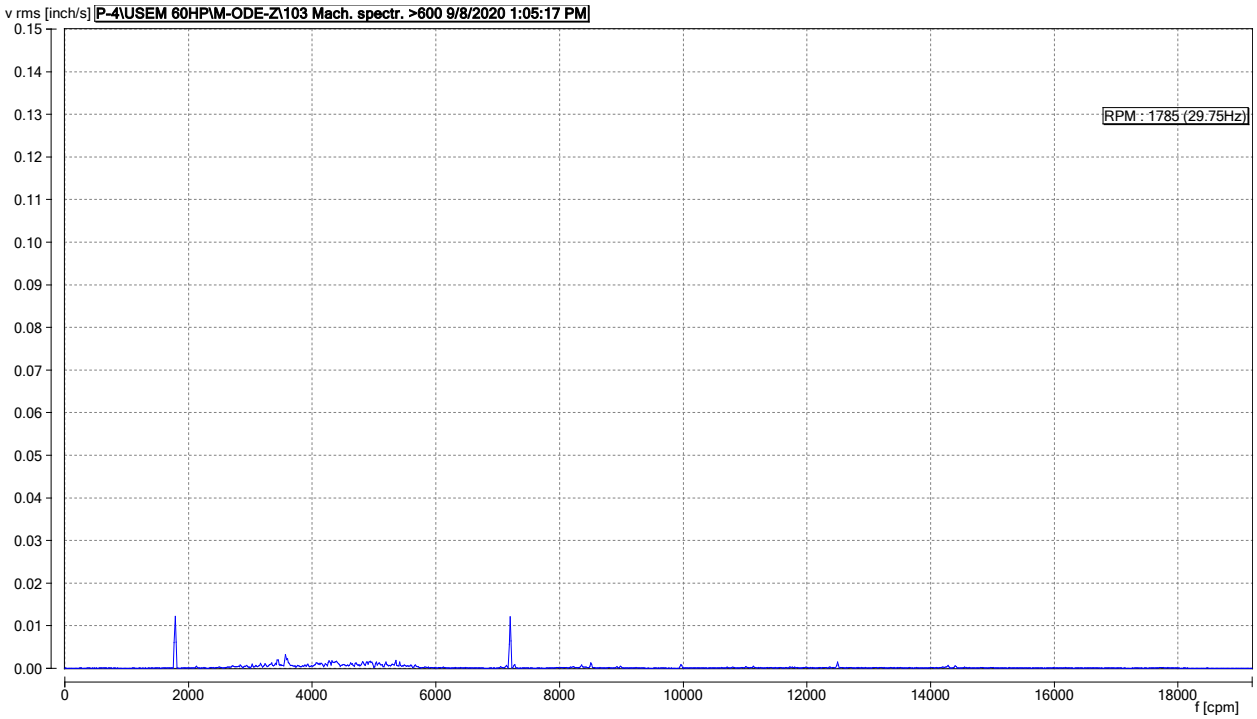

Figure 38: BP-4, M-ODE-Z. Maximum peaks are 0.012 in/sec rms at 1,785 cpm (1X run speed) and 0.012 in/sec rms at 7,200 cpm (2X electrical).

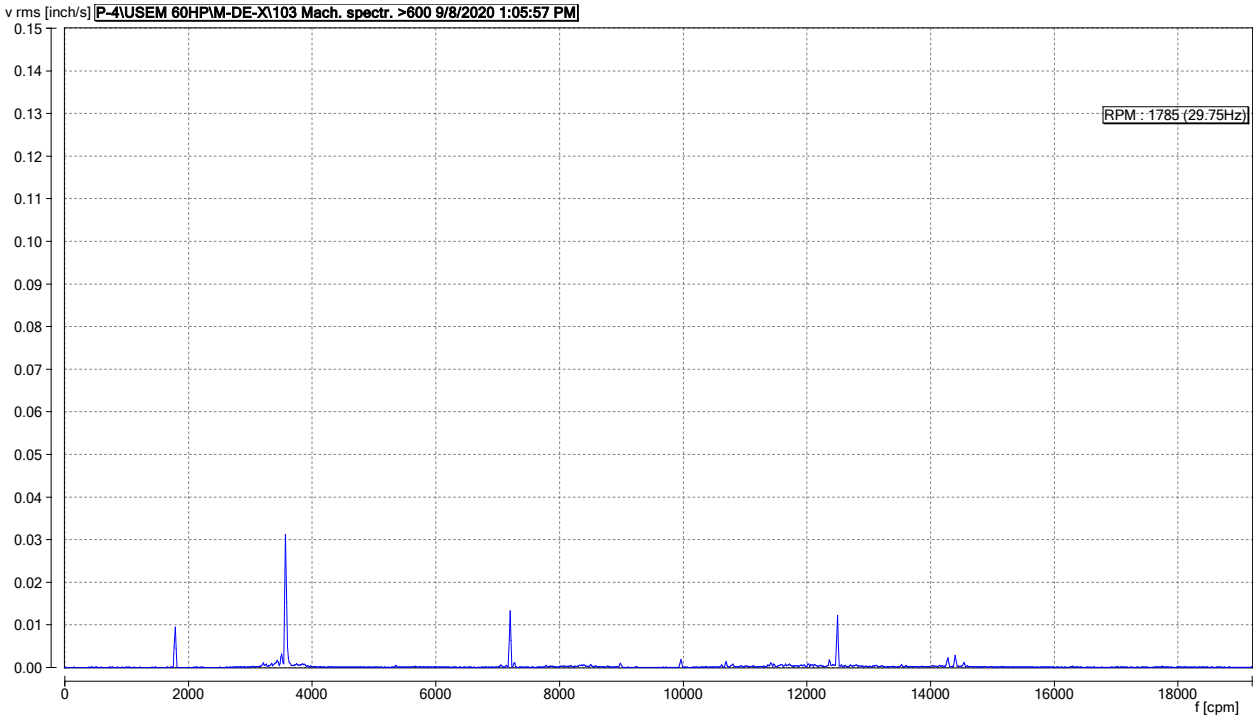

Figure 39: BP-4, M-DE-X. Maximum peak is 0.031 in/sec rms at 3,570 cpm (2X run speed).

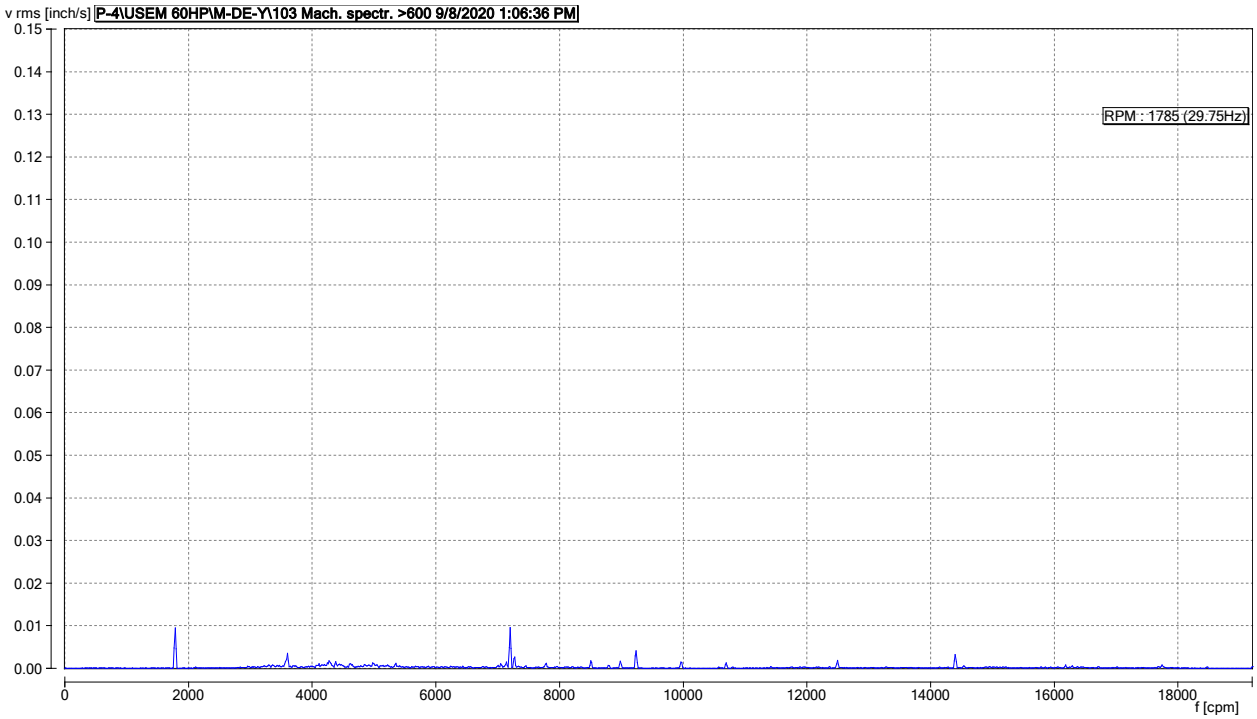

Figure 40: BP-4, M-DE-Y. All peaks are very low.

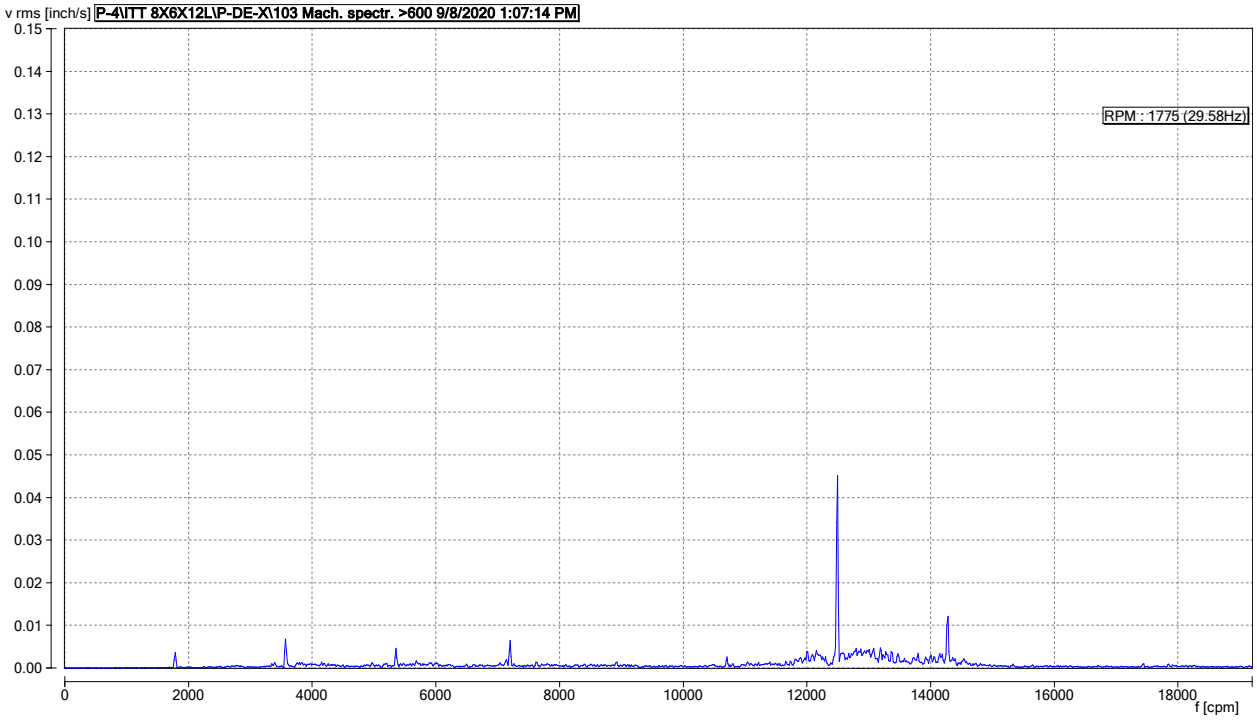

Figure 41: BP-4, P-DE-X. Maximum peak is 0.045 in/sec rms at 12,491 cpm (7X run speed).

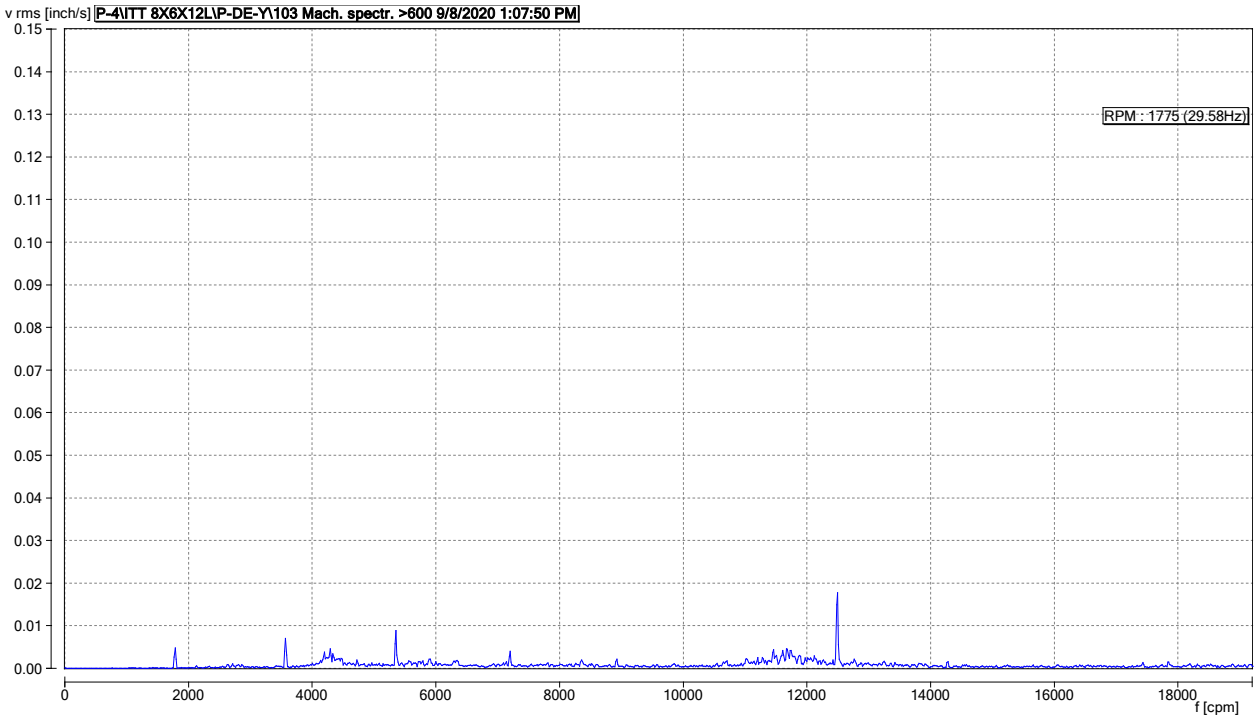

Figure 42: BP-4, P-DE-Y. Maximum peak is 0.018 in/sec rms at 12,491 cpm (7X run speed).

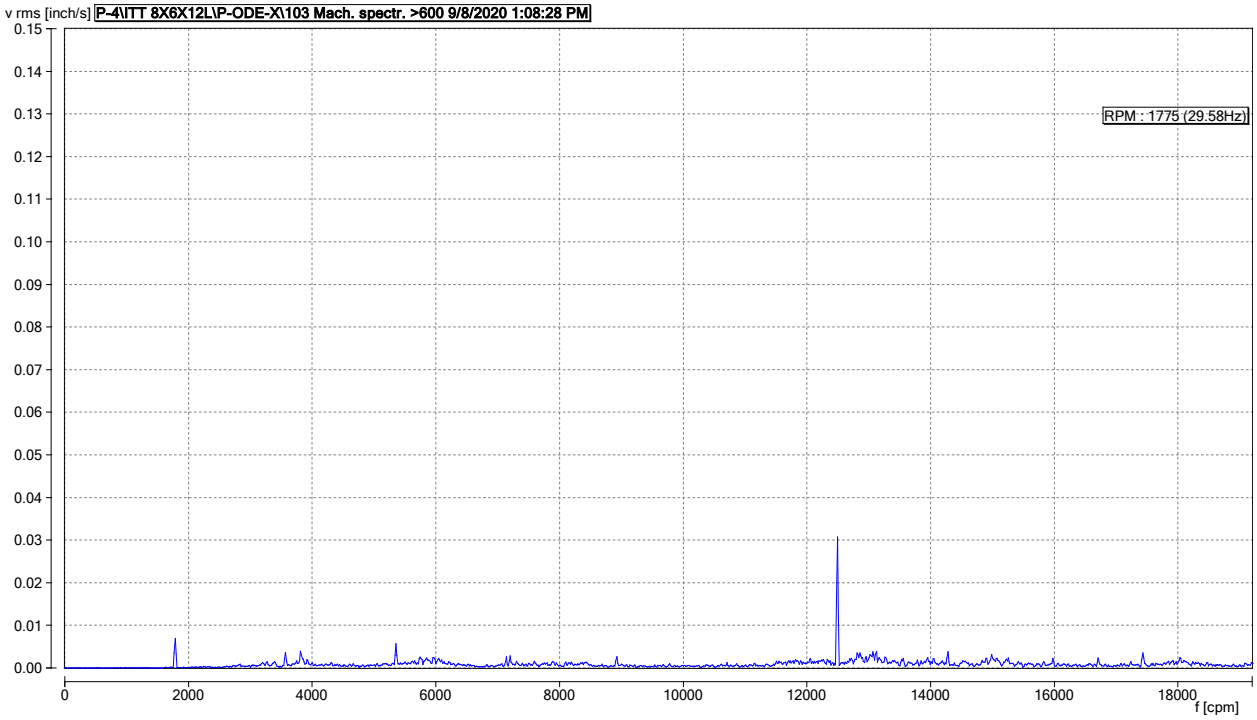

Figure 43: BP-4, P-ODE-X. Maximum peak is 0.031 in/sec rms at 12,491 cpm (7X run speed).

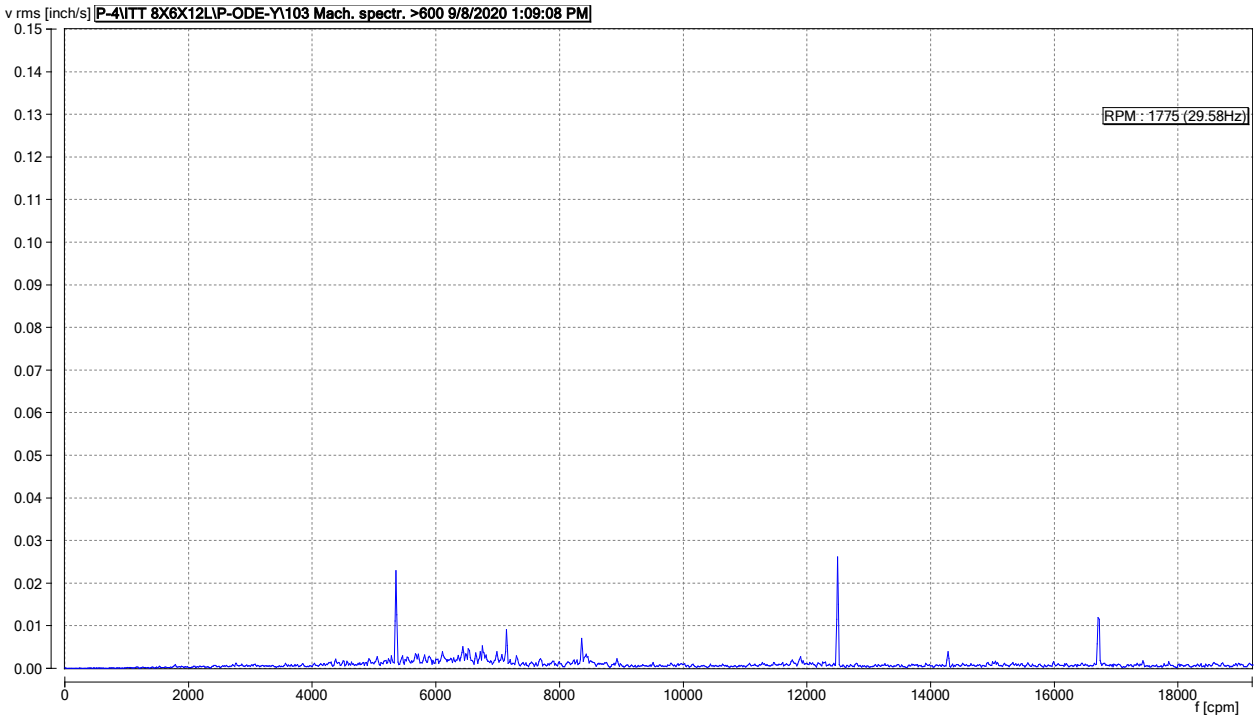

Figure 44: BP-4, P-ODE-Y. Maximum peaks are 0.026 in/sec rms at 12,495 cpm (7X run speed) and 0.023 in/sec rms at 5,355 cpm (3X run speed).

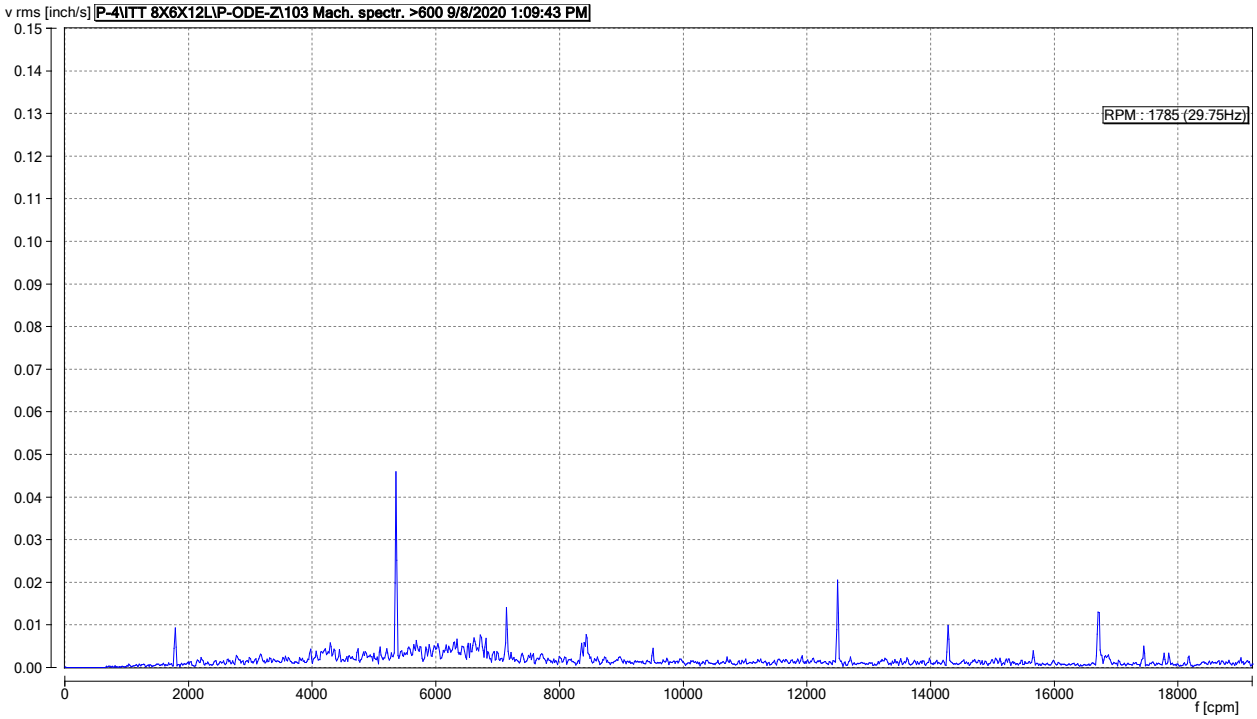

Figure 45: BP-4, P-ODE-Z. Maximum peaks are 0.046 in/sec rms at 5,355 cpm (3X run speed) and 0.020 in/sec rms at 12,498 cpm (7X run speed).

The overall vibration readings recorded can be found below in Table 4. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 4: BP-4 Overal Vibration - Velocity (in/sec rms)

Time	12:25 PM	12:45 PM	1:00 PM
Speed	1,784	1,784	1,785
POR?	Yes	Yes	Yes
M-ODE-X	0.023	0.023	0.023
M-ODE-Y	0.021	0.022	0.023
M-ODE-Z	0.034	0.039	0.045
M-DE-X	0.037	0.039	0.040
M-DE-Y	0.018	0.019	0.019
P-DE-X	0.048	0.070	0.066
P-DE-Y	0.050	0.043	0.049
P-ODE-X	0.065	0.065	0.066
P-ODE-Y	0.061	0.059	0.060
P-ODE-Z	0.100	0.092	0.106

All overall vibration readings are very low.

TEST DISCUSSIONS

- Hydraulic Operation
  - The pump is performing very well and close to the catalog curve.

- Electrical Operation
  - The maximum power recorded was 60 hp which is right at the motor rated power of 60 hp
  - According to the pump catalog curve, the motor horsepower will be exceeded when the pump exceeds 1,300 gpm.

- Mechanical Operation
  - The maximum overall vibration is 0.106 in/sec rms, below the HI recommended limits.

SUMMARY CONCLUSIONS

BP-4 pump operates close to the catalog curve and with low vibration. The motor operates very well with low vibration. The only issue is that the motor rated horsepower will be exceeded when the flow rate exceeds 1,300 gpm. If the flow is expected to exceed 1,300 gpm, it is recommended the existing motor be replaced with a larger one, 75 hp recommended.

APPENDICES

ITEM	DATE	DOCUMENT DESCRIPTION
APPENDIX A	09/08/2020	BP-1 Field Test Data
	09/08/2020	BP-2 Field Test Data
	09/08/2020	BP-3 Field Test Data
	09/08/2020	BP-4 Field Test Data

APPENDIX A

FIELD TESTING DATA

SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	Howell	**PUMP:**	American Marsh, HIM, Size 6
SERIAL NO.:	Unknown	**SERIAL NO.:**	Unknown
RATED HP:	75 hp	**RATED FLOW:**	1,400 gpm
RATED SPEED:	1,770 rpm	**RATED HEAD:**	175' TDH
FLA:	86.5 A	**RATED SPEED:**	1,750rpm

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/8/2020	**PLANT:**	Milton Water Plant
PROJECT #:	179004-02	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-1
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 8:27 AM STOP:

	TIME:	8:33 AM	9:10 AM	9:25 AM							
	RUN TIME (MIN):	6	43	58							
	FLOW METER: (GPM)	1,093.00	904.00	645.00							
	FLOW RATE (GPM):	1,093	904	645							
	SUCT. CORRECTION (FT):	0.00	0.00	0.00							
	SUCTION DIAMETER (IN):	8.00	8.00	8.00							
	SUCT. PRESSURE: (PSI)	9.10	9.10	9.30							
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):	0.76	0.52	0.26							
	DISCH. CORRECTION (FT):	0.00	0.00	0.00							
	DISCH. DIAMETER (IN):	6.00	6.00	6.00							
	DISCH. PRESSURE: (PSI)	75.50	77.00	77.80							
	DISCH. VELOCITY HEAD (FT):	2.39	1.63	0.83							
	HEAD LOSS (FT):	0.00	0.00	0.00							
	TDH (FT):	155.0	158.0	158.8							
	SPEED (RPM):	1,781	1,781	1,784							
	VOLTAGE A-B (V):	474.3	473.4	475.6							
	VOLTAGE B-C (V):	470.1	469.1	470.9							
	VOLTAGE A-C (V):	474.0	472.7	475.2							
	VOLTAGE IMBALANCE (%):	0.6	0.6	0.6							
	CURRENT A-B (AMPS):	68.4	64.0	56.2							
	CURRENT B-C (AMPS):	63.6	59.2	50.8							
	CURRENT A-C (AMPS):	66.5	61.8	54.2							
	CURRENT IMBALANCE (%):	3.9	4.0	5.5							
	POWER FACTOR:	0.92	0.92	0.91							
	INPUT POWER (kW):	50.2	46.5	40.0							
	MOTOR EFF. (%):	87.0%	87.0%	87.0%							
	SHAFT POWER (HP):	59	54	47							
SPEED CORRECTED	**TARGET SPEED (RPM):**	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760
	FLOW RATE (GPM):	1,080	893	636							
	TDH (FT):	151.4	154.3	154.6							
	POWER (HP):	56.5	52.3	44.8							
	PUMP EFF. (%):	73.1	66.5	55.4							
	WIRE TO WATER EFF (%):	63.6	57.9	48.2							
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**	0.024	0.089	0.098							
	M-NDE-X (90°):	0.049	0.109	0.117							
	M-NDE-Y (0°):	0.029	0.047	0.133							
	M-DE-X (90°):	0.058	0.131	0.133							
	M-DE-Y (0°):	0.039	0.132	0.124							
	P-DE-X (90°):	0.032	0.035	0.072							
	P-DE-Y (0°):	0.020	0.037	0.057							
	P-NDE-X (90°):	0.032	0.059	0.078							
	P-NDE-Y (0°):	0.019	0.027	0.045							
	P-NDE-AXIAL:	0.030	0.072	0.113							

NOTES:

1 - Discharge gage is station gage, could not remove to install test gage

2 - Motor vibration increased when the flow was reduced

3 - The American-Marsh HIM pump curve could not be located, an updated curve from the 6x8-15 HD pump curve was used instead

4 -

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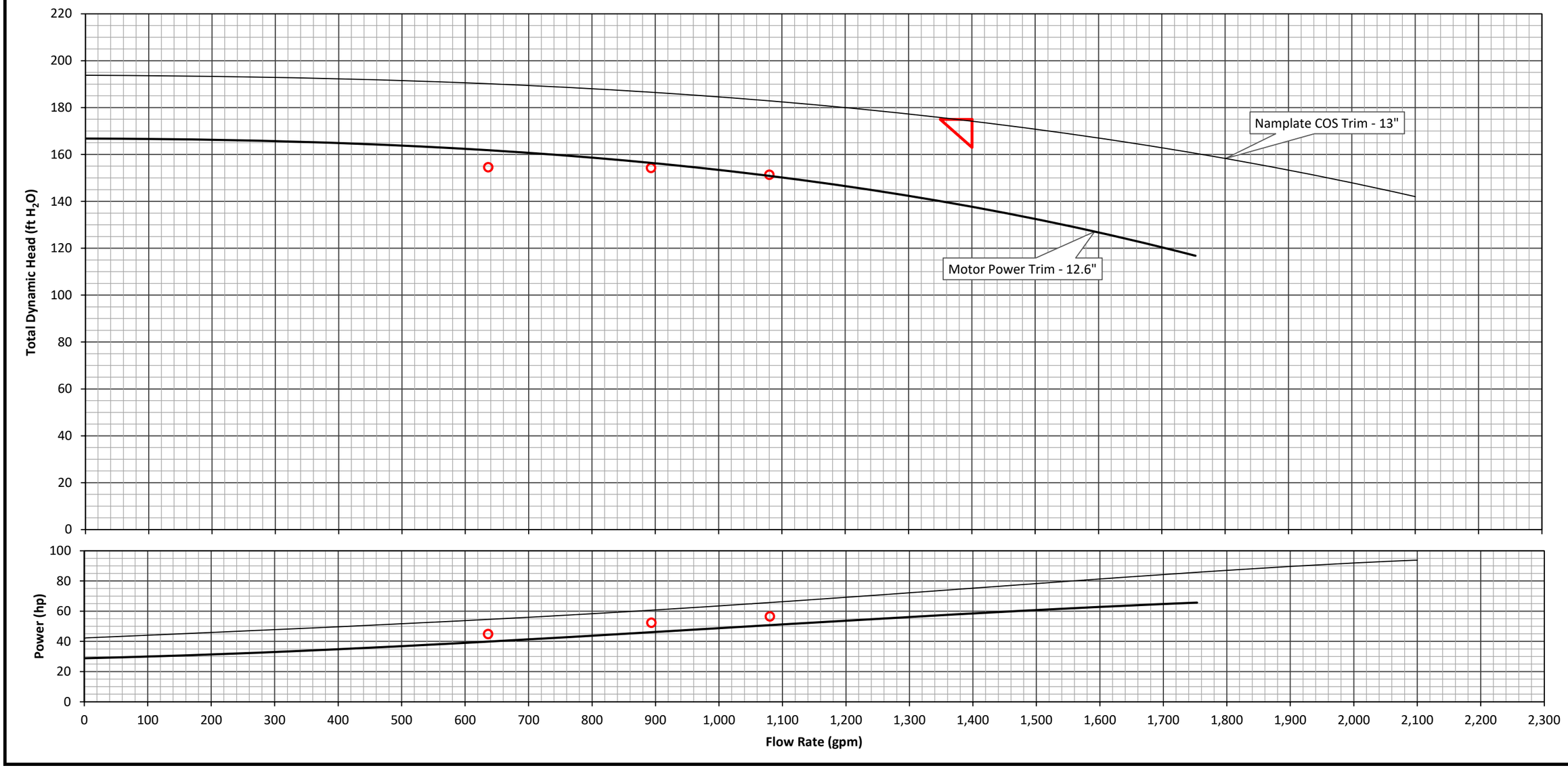
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	American Marsh	**Rated Capacity**	**[gpm]**	1,400	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	175	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	HIM, Size 6	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	1,750	**Witnessed By**	
Tag Number	P-1	**Serial Number**	Unknown	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	Howell	**PUMP:**	American Marsh, HIM, Size 6
SERIAL NO.:		**SERIAL NO.:**	45916
RATED HP:	75 hp	**RATED FLOW:**	1,400 gpm
RATED SPEED:	1,770 rpm	**RATED HEAD:**	175' TDH
FLA:	86.5 A	**RATED SPEED:**	1,750rpm

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/8/2020	**PLANT:**	Milton Water Plant
PROJECT #:	179004-02	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-2
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 9:53 AM STOP:

	TIME:		10:00 AM	10:12 AM	10:26 AM						
	RUN TIME (MIN):		7	19							
	FLOW METER:	**(GPM)**	1,323.00	819.00	1,074.00						
	FLOW RATE (GPM):		1,323	819	1,074						
	SUCT. CORRECTION (FT):		0.00	0.00	0.00						
	SUCTION DIAMETER (IN):		8.00	8.00	8.00						
	SUCT. PRESSURE:	**(PSI)**	8.88	10.45	9.78						
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):		1.11	0.42	0.73						
	DISCH. CORRECTION (FT):		0.00	0.00	0.00						
	DISCH. DIAMETER (IN):		6.00	6.00	6.00						
	DISCH. PRESSURE:	**(PSI)**	72.00	77.20	75.10						
	DISCH. VELOCITY HEAD (FT):		3.50	1.34	2.31						
	HEAD LOSS (FT):		0.00	0.00	0.00						
	TDH (FT):		148.2	155.1	152.5						
	SPEED (RPM):		1,778	1,783	1,780						
	VOLTAGE A-B (V):		473.3	474.0	474.5						
	VOLTAGE B-C (V):		469.2	469.4	469.8						
	VOLTAGE A-C (V):		472.5	472.9	473.8						
	VOLTAGE IMBALANCE (%):		0.5	0.6	0.6						
	CURRENT A-B (AMPS):		73.3	60.2	68.0						
	CURRENT B-C (AMPS):		67.0	53.4	61.0						
	CURRENT A-C (AMPS):		71.9	58.4	66.6						
	CURRENT IMBALANCE (%):		5.3	6.8	6.4						
	POWER FACTOR:		0.93	0.91	0.92						
	INPUT POWER (kW):		53.5	43.0	49.4						
	MOTOR EFF. (%):		87%	87%	87%						
	SHAFT POWER (HP):		62	50	58						
SPEED CORRECTED	**TARGET SPEED (RPM):**		1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760	1,760
	FLOW RATE (GPM):		1,310	808	1,062						
	TDH (FT):		145.2	151.1	149.1						
	POWER (HP):		60.5	48.2	55.7						
	PUMP EFF. (%):		79.4	64.0	71.7						
	WIRE TO WATER EFF (%):		69.1	55.7	62.4						
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**		0.030	0.028	0.032						
	M-NDE-X (90°):		0.054	0.058	0.052						
	M-NDE-Y (0°):		0.043	0.039	0.034						
	M-DE-X (90°):		0.064	0.063	0.072						
	M-DE-Y (0°):		0.036	0.037	0.035						
	P-DE-X (90°):		0.036	0.041	0.029						
	P-DE-Y (0°):		0.018	0.032	0.027						
	P-NDE-X (90°):		0.040	0.045	0.034						
	P-NDE-Y (0°):		0.023	0.028	0.025						
	P-NDE-AXIAL:		0.036	0.050	0.039						

NOTES:

1 - Discharge gage is station gage, could not remove to install test gage

2 -

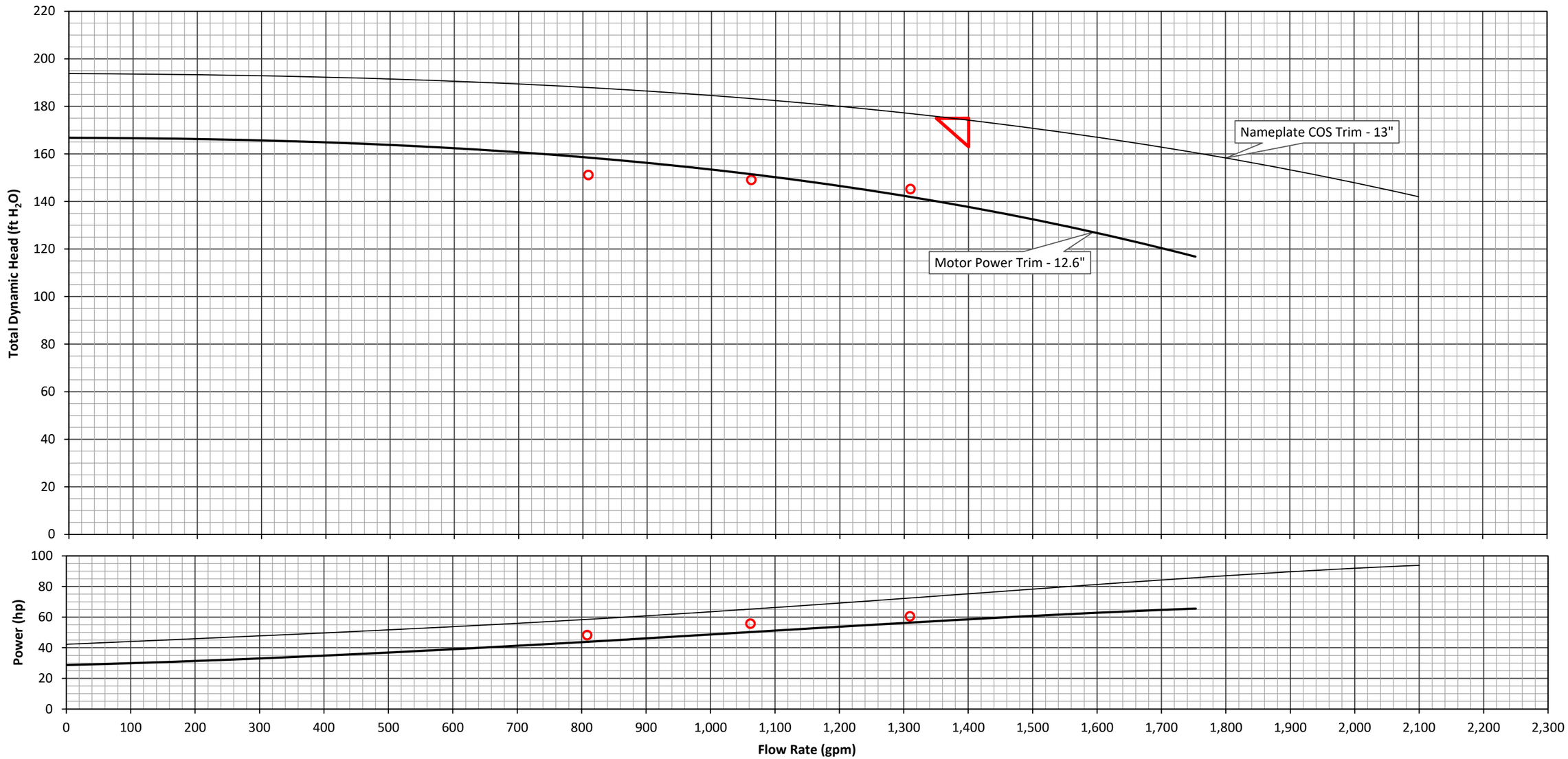
3 -

4 -

Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	American Marsh	**Rated Capacity**	**[gpm]**	1,400	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	175	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	HIM, Size 6	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	1,750	**Witnessed By**	
Tag Number	P-2	**Serial Number**	45916	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	Fairbanks-Morse	**PUMP:**	Fairbanks-Morse
SERIAL NO.:	F356340	**SERIAL NO.:**	Unknown
RATED HP:	60 hp	**RATED FLOW:**	Unknown
RATED SPEED:	1,765 rpm	**RATED HEAD:**	Unknown
FLA:	71 A	**RATED SPEED:**	Unknown

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/8/2020	**PLANT:**	Milton Water Plant
PROJECT #:	179004-02	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-3
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 10:53 AM STOP:

	TIME:		11:01 AM	11:25 AM	11:45 AM						
	RUN TIME (MIN):		8	32	52						
	FLOW METER:	**(GPM)**	1,163.00	995.00	741.00						
	FLOW RATE (GPM):		1,163	995	741						
	SUCT. CORRECTION (FT):		0.00	0.00	0.00						
	SUCTION DIAMETER (IN):		8.00	8.00	8.00						
	SUCT. PRESSURE:	**(PSI)**	8.22	8.66	9.10						
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):		0.86	0.63	0.35						
	DISCH. CORRECTION (FT):		0.00	0.00	0.00						
	DISCH. DIAMETER (IN):		6.00	6.00	6.00						
	DISCH. PRESSURE:	**(FT)**	155.00	161.00	166.00						
	DISCH. VELOCITY HEAD (FT):		2.70	1.98	1.10						
	HEAD LOSS (FT):		0.00	0.00	0.00						
	TDH (FT):		137.9	142.3	145.7						
	SPEED (RPM):		1,766	1,767	1,771						
	VOLTAGE A-B (V):		473.8	472.6	471.8						
	VOLTAGE B-C (V):		468.9	467.1	465.9						
	VOLTAGE A-C (V):		472.8	471.2	470.0						
	VOLTAGE IMBALANCE (%):		0.6	0.7	0.7						
	CURRENT A-B (AMPS):		62.2	59.4	53.6						
	CURRENT B-C (AMPS):		57.2	54.0	48.0						
	CURRENT A-C (AMPS):		60.3	57.1	51.0						
	CURRENT IMBALANCE (%):		4.5	5.0	5.6						
	POWER FACTOR:		0.89	0.89	0.88						
	INPUT POWER (kW):		43.5	40.9	36.3						
	MOTOR EFF. (%):		90.0%	90.0%	90.0%						
	SHAFT POWER (HP):		52	49	44						
SPEED CORRECTED	**TARGET SPEED (RPM):**		1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775
SPEED CORRECTED	**FLOW RATE (GPM):**		1,169	1,000	743						
SPEED CORRECTED	**TDH (FT):**		139.3	143.6	146.4						
SPEED CORRECTED	**POWER (HP):**		53.2	50.0	44.1						
SPEED CORRECTED	**PUMP EFF. (%):**		77.2	72.5	62.3						
SPEED CORRECTED	**WIRE TO WATER EFF (%):**		69.5	65.3	56.0						
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**		0.017	0.018	0.018						
VIBRATION (IN/SEC RMS)	**M-NDE-X (90°):**		0.056	0.060	0.060						
VIBRATION (IN/SEC RMS)	**M-NDE-Y (0°):**		0.025	0.024	0.028						
VIBRATION (IN/SEC RMS)	**M-DE-X (90°):**		0.050	0.055	0.059						
VIBRATION (IN/SEC RMS)	**M-DE-Y (0°):**		0.021	0.023	0.025						
VIBRATION (IN/SEC RMS)	**P-DE-X (90°):**		0.062	0.087	0.116						
VIBRATION (IN/SEC RMS)	**P-DE-Y (0°):**		0.044	0.056	0.067						
VIBRATION (IN/SEC RMS)	**P-NDE-X (90°):**		0.045	0.051	0.060						
VIBRATION (IN/SEC RMS)	**P-NDE-Y (0°):**		0.040	0.042	0.052						
VIBRATION (IN/SEC RMS)	**P-NDE-AXIAL:**		0.041	0.043	0.056						

NOTES:

1 - Smith Pump gages used on suction and discharge

2 -

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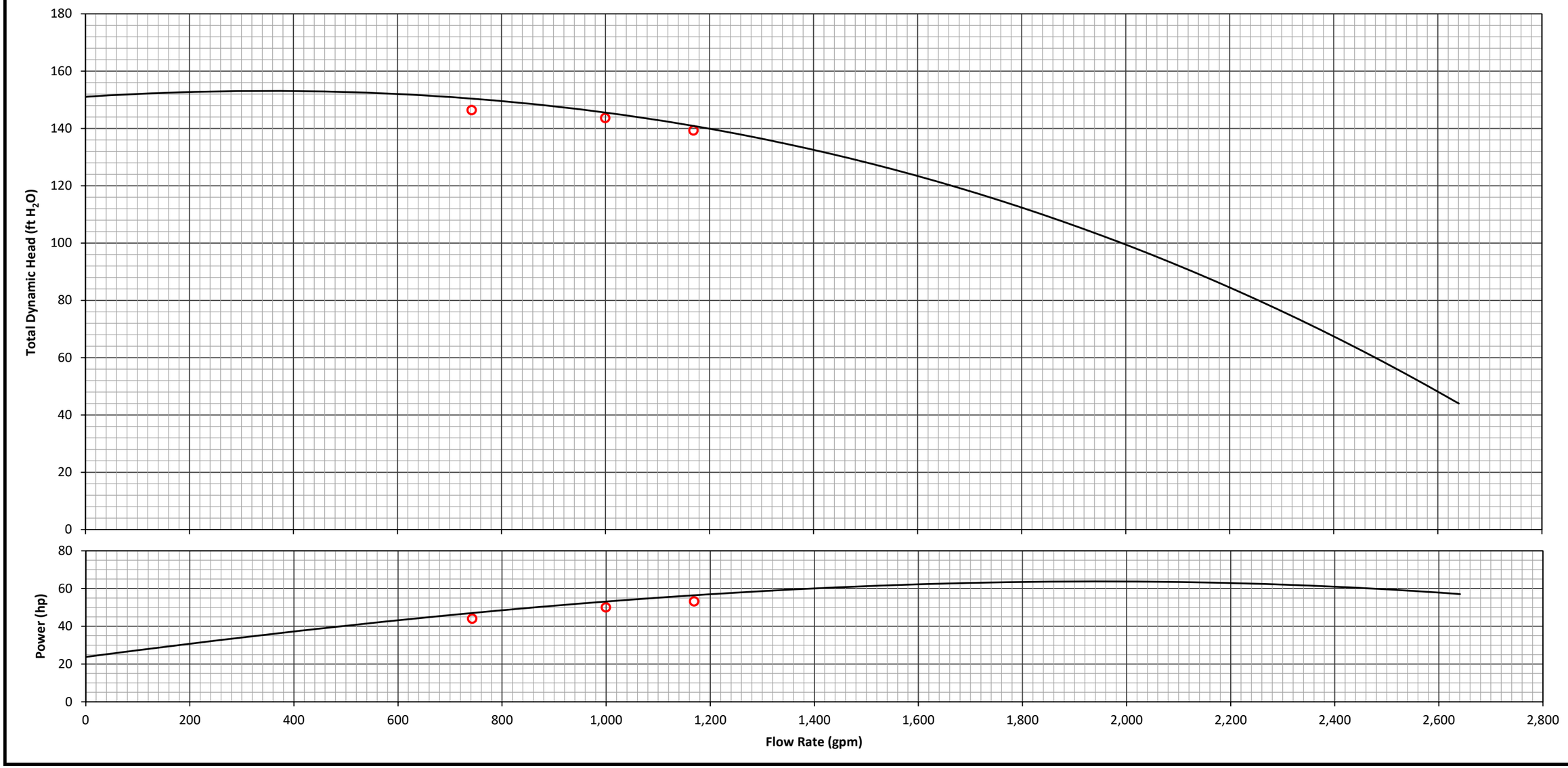
Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	Fairbanks-Morse	**Rated Capacity**	**[gpm]**	Unknownn	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	Unknownn	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	**1823, 6"**	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	**1,775**	**Witnessed By**	
Tag Number	P-3	**Serial Number**	Unknown	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	USEM	**PUMP:**	ITT A-C 8100, 8x6x12L, 12.8" trim
SERIAL NO.:	F07-H649-M	**SERIAL NO.:**	1-74417-01-1
RATED HP:	60 hp	**RATED FLOW:**	1,500 gpm
RATED SPEED:	1,785 rpm	**RATED HEAD:**	132' TDH
FLA:	70 A	**RATED SPEED:**	1,775 rpm

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/8/2020	**PLANT:**	Milton Water Plant
PROJECT #:	179004-02	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-4
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 12:13 PM STOP:

	TIME:	12:25 PM	12:45 PM	1:00 PM							
	RUN TIME (MIN):	12	32								
	FLOW METER 1: (GPM)	1,301.00	1,159.00	1,065.00							
	FLOW RATE (GPM):	1,301	1,159	1,065							
	SUCT. CORRECTION (FT):	0.00	0.00	0.00							
	SUCTION DIAMETER (IN):	8.00	8.00	8.00							
	SUCT. PRESSURE: (PSI)	7.35	7.72	8.06							
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):	1.07	0.85	0.72							
	DISCH. CORRECTION (FT):	0.00	0.00	0.00							
	DISCH. DIAMETER (IN):	6.00	6.00	6.00							
	DISCH. PRESSURE: (FT)	158.00	164.00	171.00							
	DISCH. VELOCITY HEAD (FT):	3.38	2.68	2.27							
	HEAD LOSS (FT):	0.00	0.00	0.00							
	TDH (FT):	143.3	148.0	153.9							
	SPEED (RPM):	1,784	1,784	1,785							
	VOLTAGE A-B (V):	470.8	469.4	470.4							
	VOLTAGE B-C (V):	465.1	463.8	464.3							
	VOLTAGE A-C (V):	469.3	468.3	469.4							
	VOLTAGE IMBALANCE (%):	0.7	0.7	0.8							
	CURRENT A-B (AMPS):	71.1	68.3	65.4							
	CURRENT B-C (AMPS):	66.4	63.6	60.3							
	CURRENT A-C (AMPS):	68.9	66.5	63.6							
	CURRENT IMBALANCE (%):	3.5	3.8	4.4							
	POWER FACTOR:	0.86	0.85	0.85							
	INPUT POWER (kW):	47.9	45.7	43.6							
	MOTOR EFF. (%):	93.6%	93.6%	93.6%							
	SHAFT POWER (HP):	60	57	55							
SPEED CORRECTED	**TARGET SPEED (RPM):**	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775
SPEED CORRECTED	**FLOW RATE (GPM):**	1,294	1,153	1,059							
SPEED CORRECTED	**TDH (FT):**	141.9	146.5	152.2							
SPEED CORRECTED	**POWER (HP):**	59.1	56.4	53.8							
SPEED CORRECTED	**PUMP EFF. (%):**	78.4	75.6	75.6							
SPEED CORRECTED	**WIRE TO WATER EFF (%):**	73.4	70.8	70.8							
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**	0.021	0.022	0.023							
VIBRATION (IN/SEC RMS)	**M-NDE-X (90°):**	0.034	0.039	0.045							
VIBRATION (IN/SEC RMS)	**M-NDE-Y (0°):**	0.023	0.023	0.023							
VIBRATION (IN/SEC RMS)	**M-DE-X (90°):**	0.037	0.039	0.040							
VIBRATION (IN/SEC RMS)	**M-DE-Y (0°):**	0.018	0.019	0.019							
VIBRATION (IN/SEC RMS)	**P-DE-X (90°):**	0.048	0.070	0.066							
VIBRATION (IN/SEC RMS)	**P-DE-Y (0°):**	0.050	0.043	0.049							
VIBRATION (IN/SEC RMS)	**P-NDE-X (90°):**	0.065	0.065	0.066							
VIBRATION (IN/SEC RMS)	**P-NDE-Y (0°):**	0.061	0.059	0.060							
VIBRATION (IN/SEC RMS)	**P-NDE-AXIAL:**	0.100	0.092	0.106							

NOTES:

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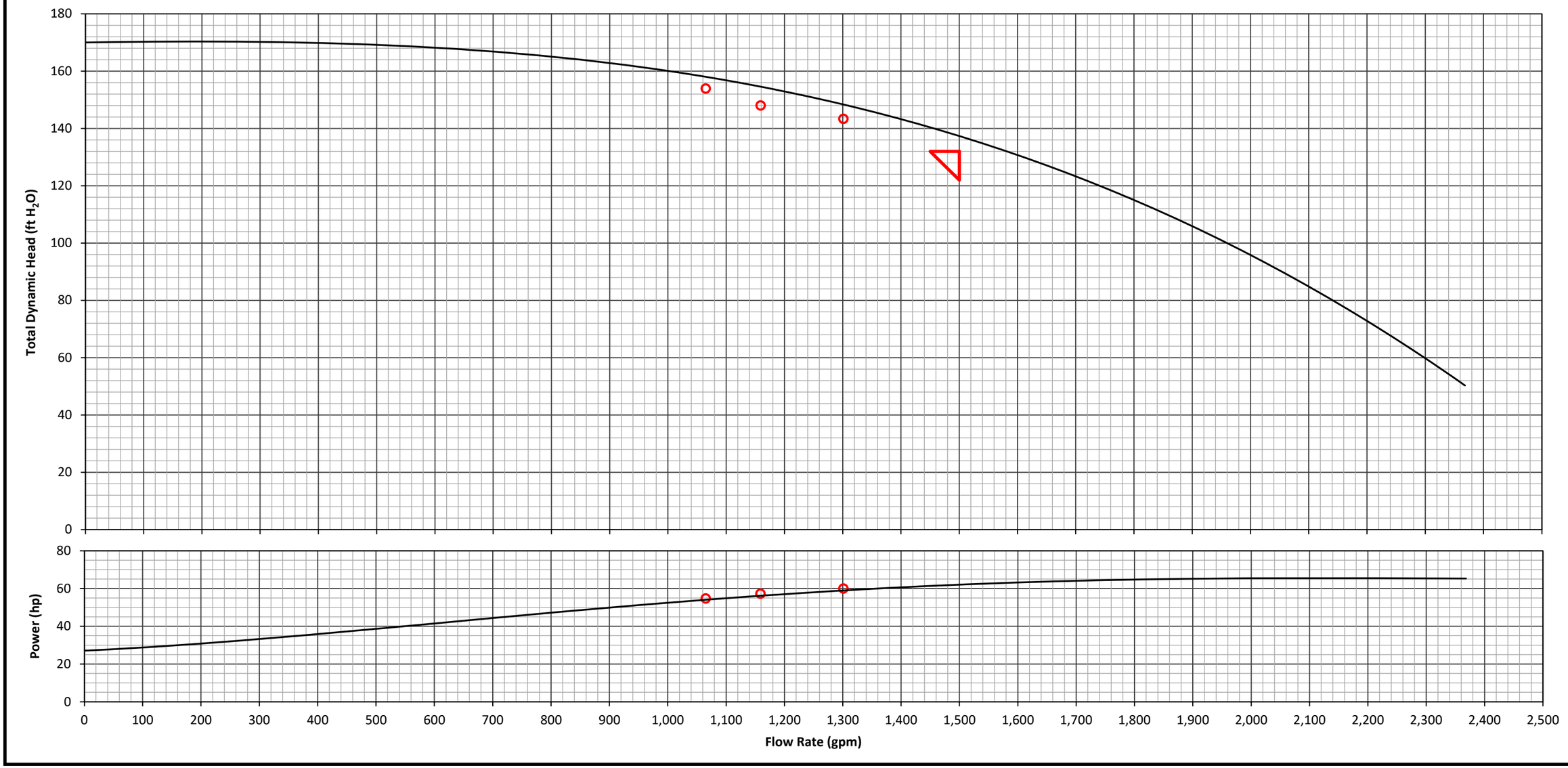
FIELD PERFORMANCE TEST

Project Number	179004-02	**Pump Mfg**	ITT A-C	**Rated Capacity**	**[gpm]**	1,500	**Tested Date**	9/8/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	132	**Tested By**	Shane Wallace
Plant	Milton St Water Plant	**Pump Model**	8100, 8x6x12L, 12.8" trim	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	1,775	**Witnessed By**	
Tag Number	P-4	**Serial Number**	1-74417-01-1	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



WAKEFOREST PUMP STATION FIELD ASSESSMENT

CONTRACTOR: N/A

ENGINEER: Freese & Nichols, Inc.

OWNER: **CITY OF WEST UNIVERSITY PLACE**

PUMP STATIONS: Wakeforest Pump Station

SPECIFICATIONS: NONE

EQUIPMENT: P-5
Aurora 411 BF, 5x5x15, 1 Stg HSC, 1,750 rpm, Serial No: 89-02378 **|** Marathon Electric Horizontal Motor, 60 hp, 1,775 rpm, 460 V, 74 FLA, Serial #: UJ 364TSTFS8026BP

P-6
Aurora 411 BF, 5x5x15, 1 Stg HSC, 1,500 gpm @ 145' TDH, 1,750 rpm, Serial No: 92-16929 **|** Baldor Electric Horizontal Motor, 75 hp, 1,780 rpm, 460 V, 85.9 FLA, Serial #: A1208072074

REVISION RECORD

REVISION	DATE	DESCRIPTION	BY
0	11/19/2020	Initial Release	S. Wallace

EXECUTIVE SUMMARY

BP-5 pump performs close to the assumed catalog curve, but it is difficult to say whether it performs close to the original curve. The pump and motor vibration spectrums and overall values are very low. This unit is operating very well.

BP-6 motor vibration signatures show a bearing outer race defect, but it is difficult to determine which motor bearing has the issue. There is also a peak at 5.93X which does not line up with a bearing fault or any other normal faults. The pump spectrums do not show any significant issues, but it appears that the overall vibration levels are high due to a raised noise floor at the higher frequencies; this is potentially a bearing issue. The pump operates fairly close to the catalog curve. It is recommended the pump and motor be monitored to ensure the vibration levels and bearing faults do not increase in severity.

REPORT OUTLINE

GENERAL ARRANGEMENT

There are two (2) horizontal split case pumps at this station. All units are run across the line at a constant speed.

The catalog curve for the pump can be found below. The pump model numbers are the same but the impeller trims, and therefore the conditions of service, are different. The conditions of service for BP-6 are shown with the red triange.

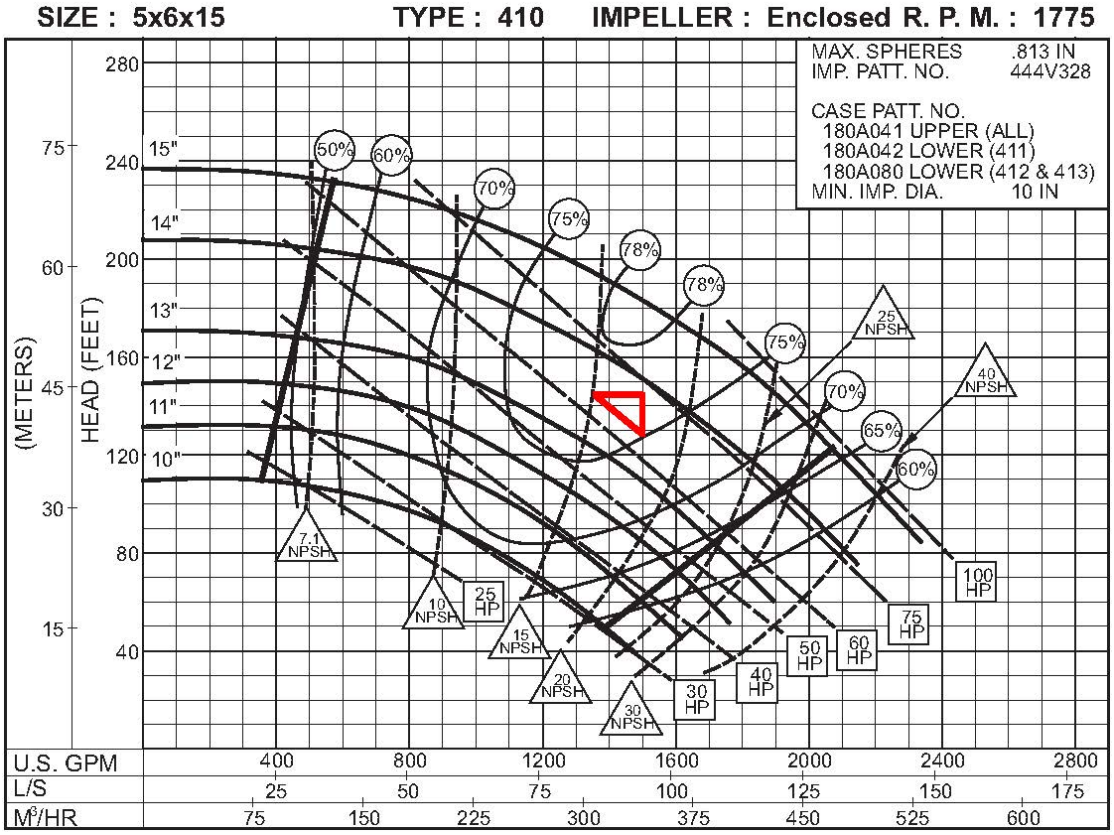


Figure 1: BP-5 & BP-6 Catalog Curve. BP-6 conditions of service shown by the red triangle.

TYPES OF TESTS

Smith Pump performed a Pump Performance Test, Vibration Test, and a Visual Inspection on each unit. The details of each test are outlined below.

Pump Performance Test

- Test pump at full speed with a 100% open valve and two points with a partially closed valve.
- Record shaft speed (rpm), flow rate, wet well level, discharge pressure, and power.

Vibration Test

- Measure filtered vibration spectra and overall vibration values in three (3) orthogonal planes at the motor non-drive end (NDE) bearing housing, two (2) orthogonal planes at the motor drive end (DE) bearing housing, two (2) orthogonal planes at the pump DE bearing housing, and three (3) orthogonal planes at the motor NDE bearing housing.

Visual Inspection

- Review baseplate design, material conditions, and piping.

ACCEPTANCE CRITERIA

None

TESTING VARIANCES

None

TESTING ARRANGEMENT

- Flow Rate – Recorded with Smith Pump's GE Panametrics PT878 portable strap-on flowmeter with the serial number 02368. The flow meter was located on the discharge header just inside the building.

- Suction Pressure – The suction pressure was recorded with an Omega Engineering PX459-050A5V pressure transducer which measures from 0 to 50 psia; the serial number is 466962. This transducer was located on the suction of each pump.

- Discharge Pressure – Recorded with Smith Pump's Winchester Model 1 digital pressure gauge with a range of 30 in Hg to 3,000 psi. The serial number for this gauge is 44518. The pressure gauge was located on the discharge of each pump.

- Shaft Speed – Recorded with Smith Pump's Monarch AFG3021B tachometer. The serial number of this device is 1520757. The serial number on BP-5 could not be measured due to the coupling guard.

- Vibration – Recorded using Smith Pump's Pruftechnik VibXpert VIB 5.300. The serial number of this device is 00558.

- Power – Recorded using a rented Fluke 1738 3-phase power quality logger. The serial number for this device is 35273147.

TEST RESULTS: BP-5

TEST RESULTS

The composite curve in Figure 2 below shows field data points plotted against the original factory test curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Recorded using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

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FIELD PERFORMANCE TEST

Project Number	179004-01	**Pump Mfg**	Aurora	**Rated Capacity**	[gpm]	Unknownn	**Tested Date**	9/15/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	Unknownn	**Tested By**	Shane Wallace
Plant	Wakeforest Water Plant	**Pump Model**	411, 5x6x15	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,775	**Witnessed By**	
Tag Number	P-5	**Serial Number**	89-02378	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

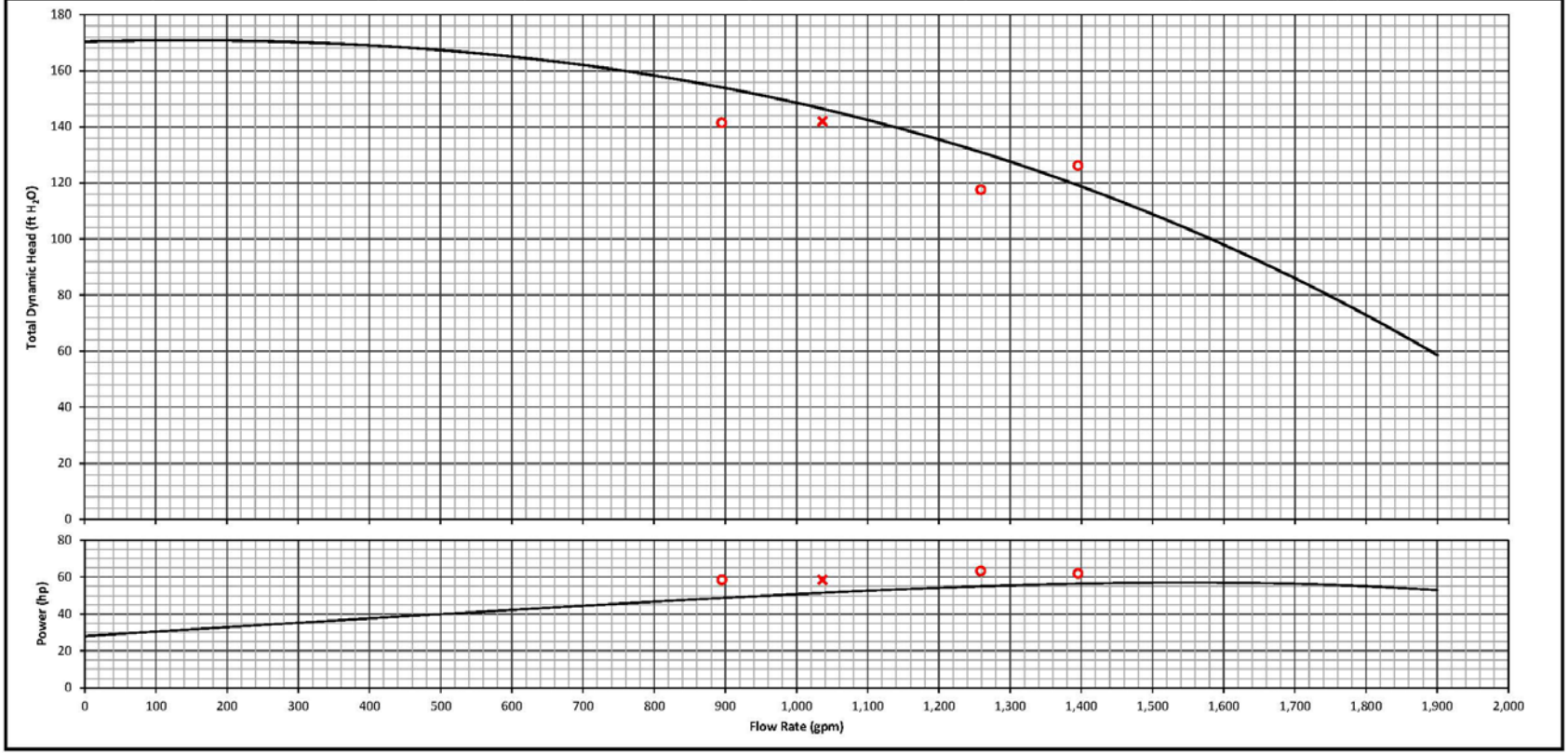

Figure 2: BP-5 Field Test Data

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-5. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

The position of Smith Pump's flow meter was ideal for most of the data points recorded but the low flow condition on BP-5 was well below the curve. The on-site accumulation flow meter was used at this point, shown with an "x" on the curve, which gave a reading much closer to the catalog curve.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the catalog curve at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below in Figure 3 to Figure 12 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

All spectral peaks on the pump and motor are very low.

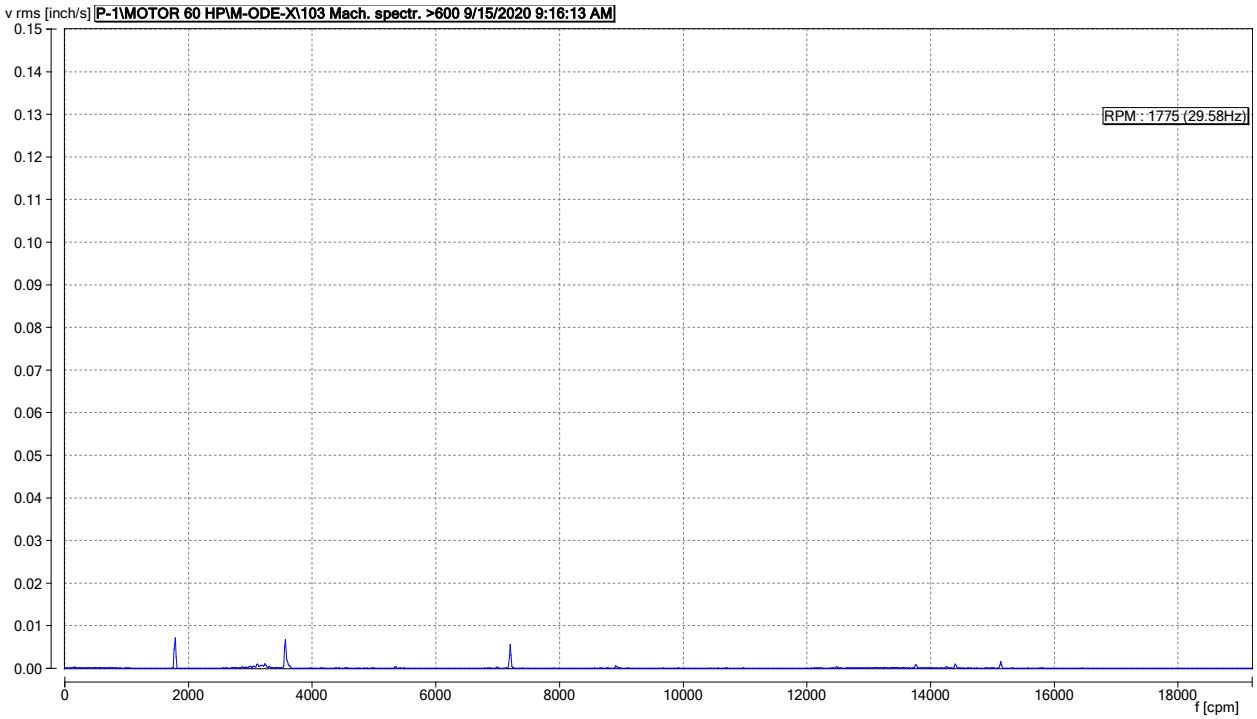

Figure 3: BP-5, M-ODE-X. All peaks are low.

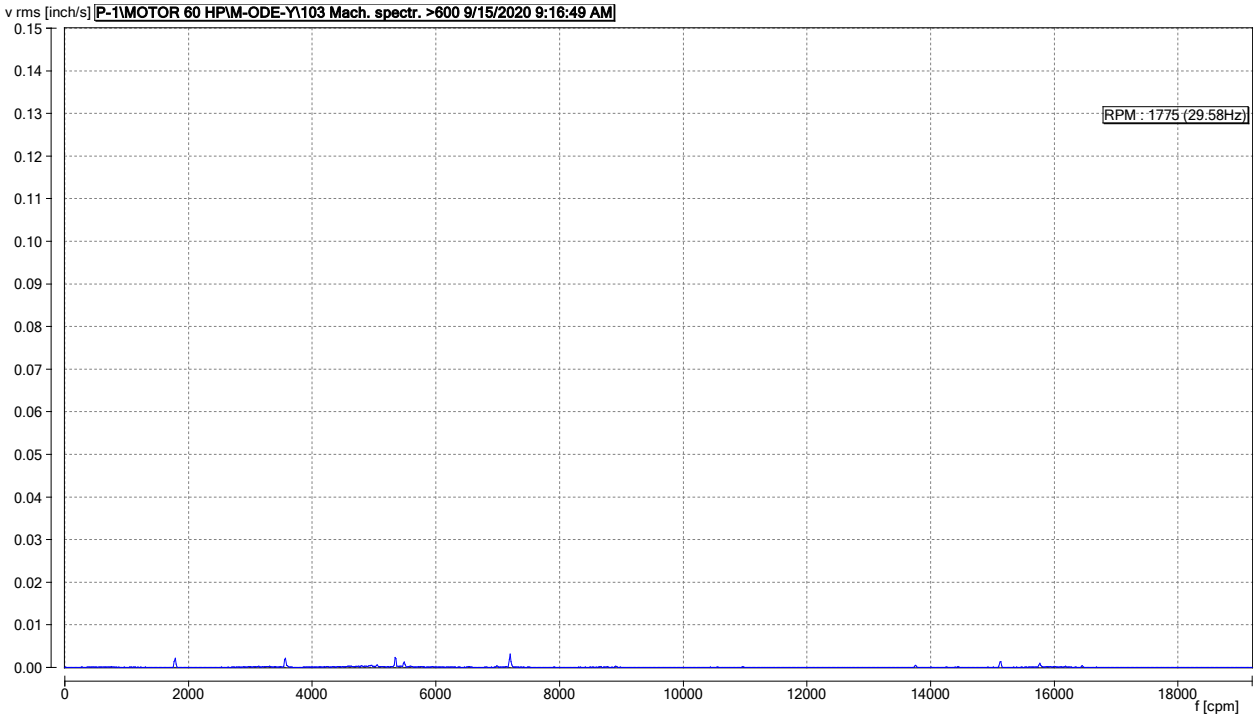

Figure 4: BP-5, M-ODE-Y. All peaks are low.

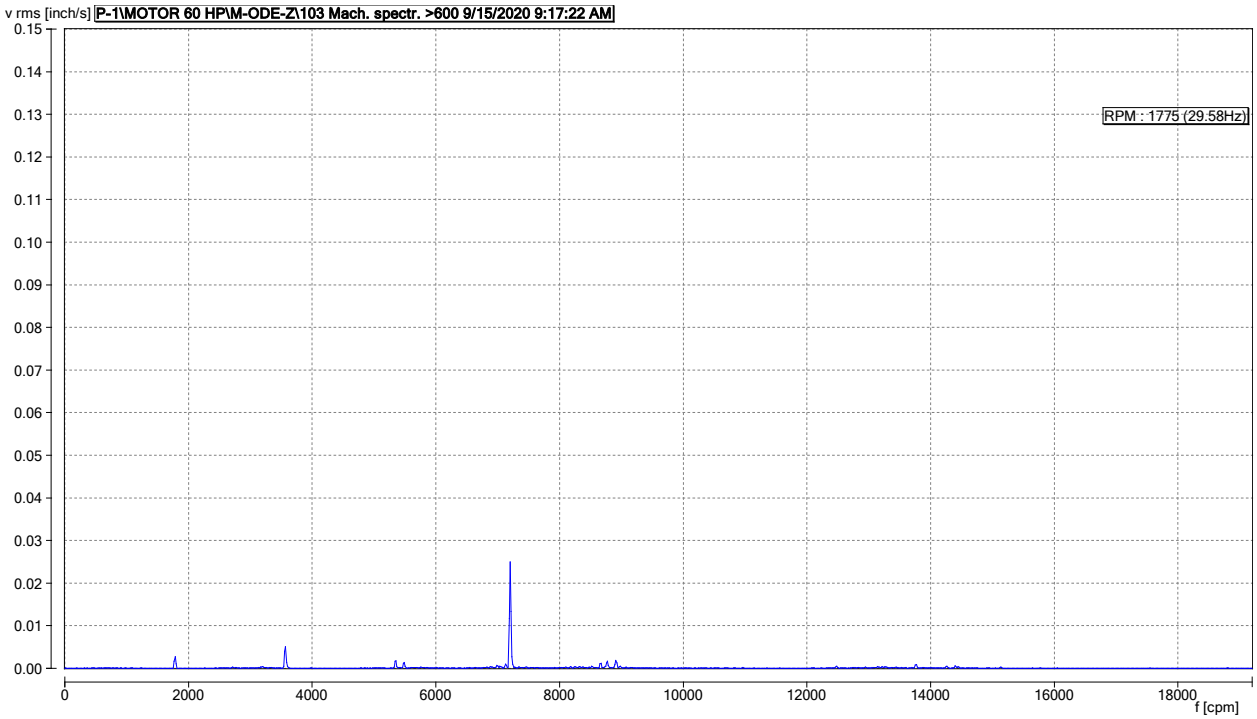

Figure 5: BP-5, M-ODE-Z. Maximum peaks is 0.025 in/sec rms at 7,200 cpm (2X electrical).

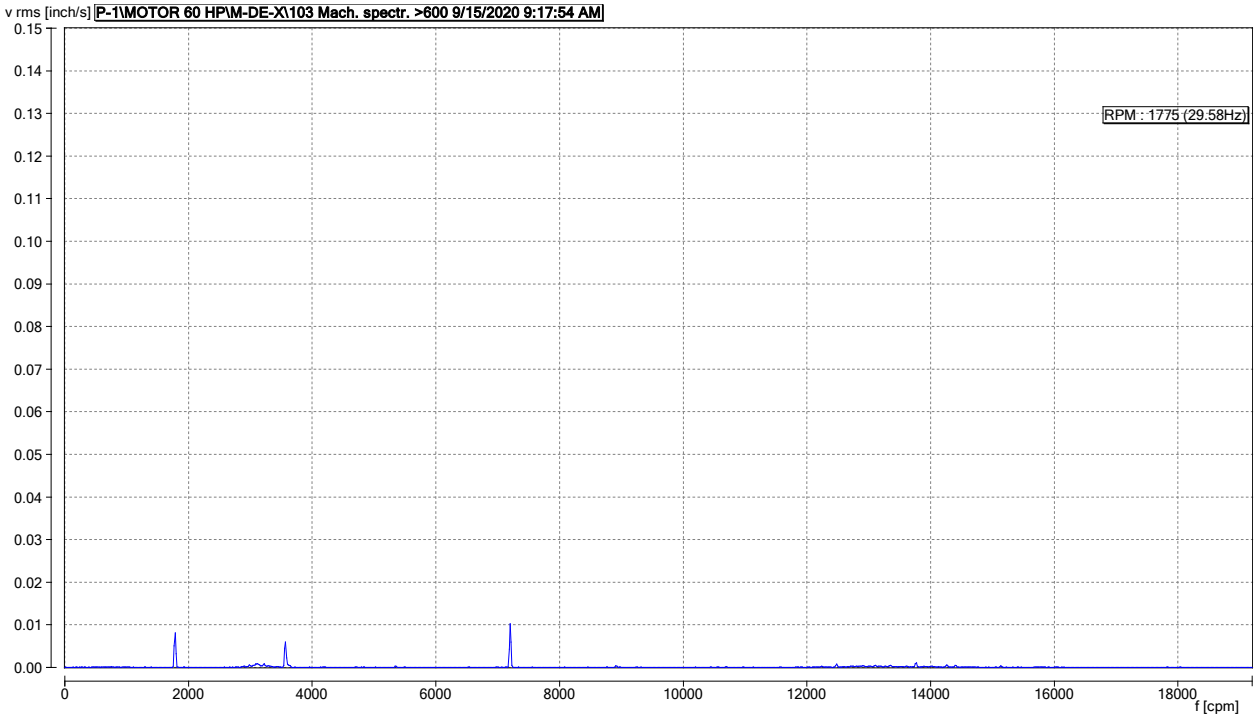

Figure 6: BP-5, M-DE-X. All peaks are low.

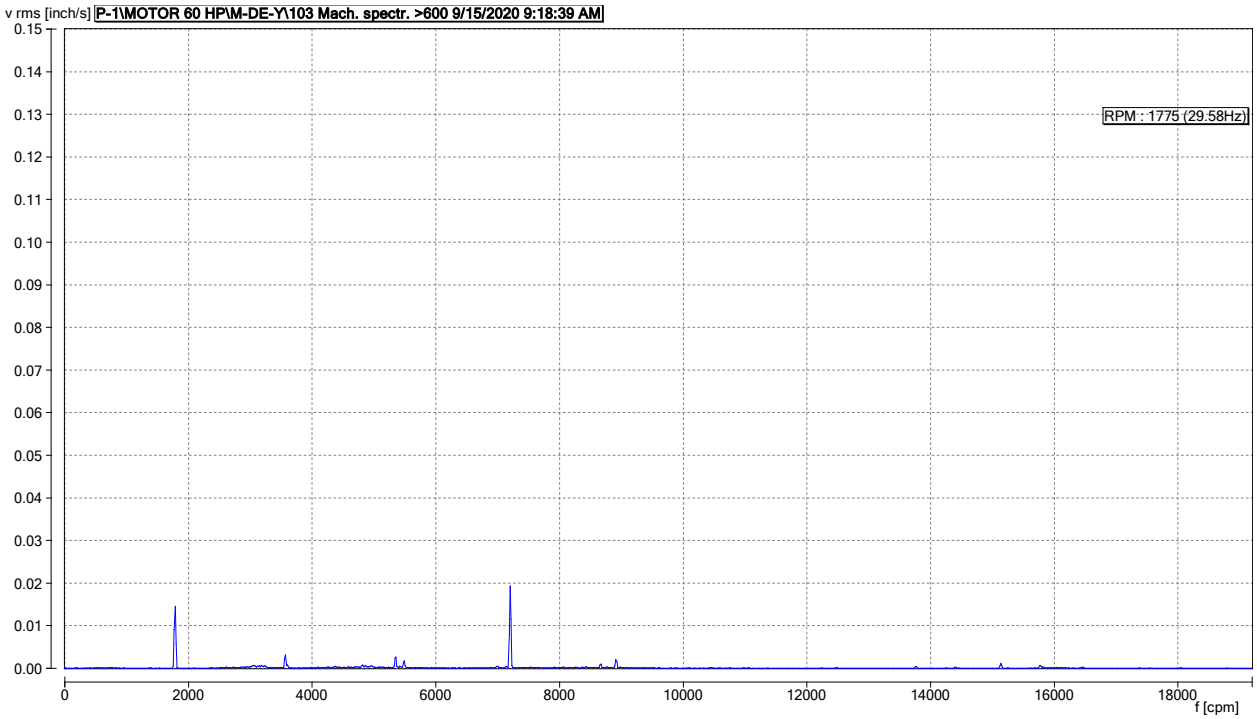

Figure 7: BP-5, M-DE-Y. Maximum peak is 0.019 in/sec rms at 7,203 cpm (2X electrical).

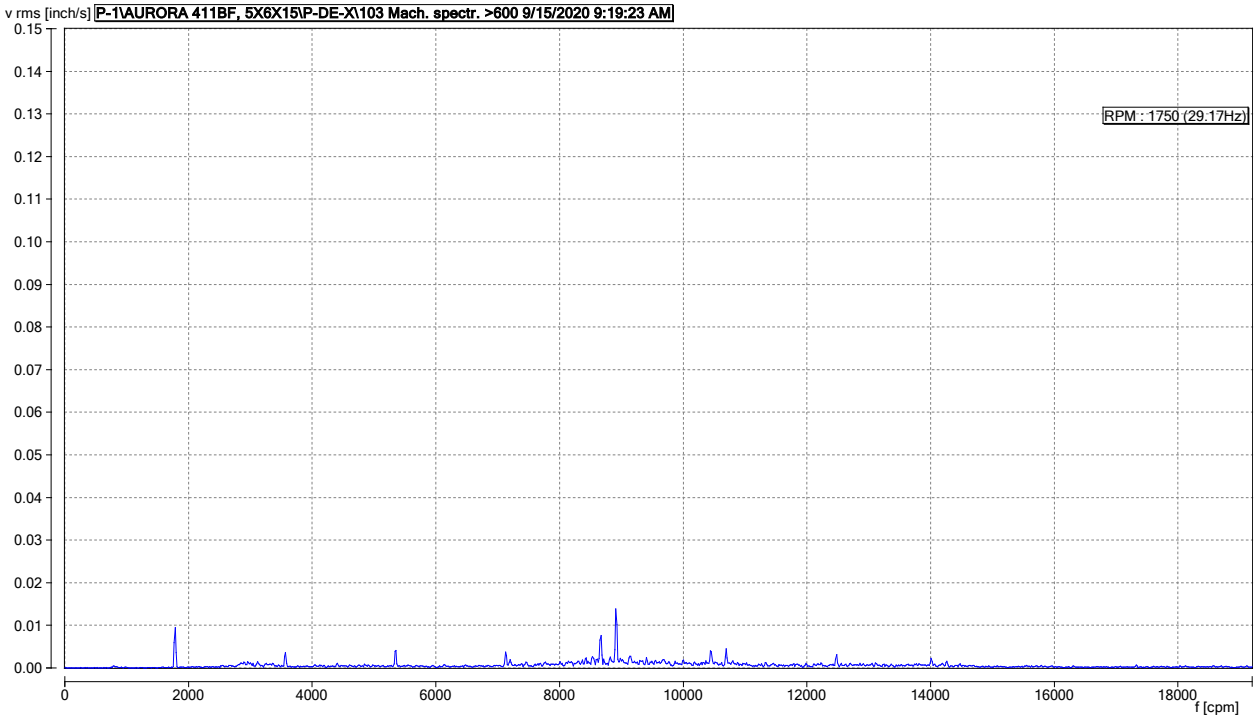

Figure 8: BP-5, P-DE-X. All peaks are low.

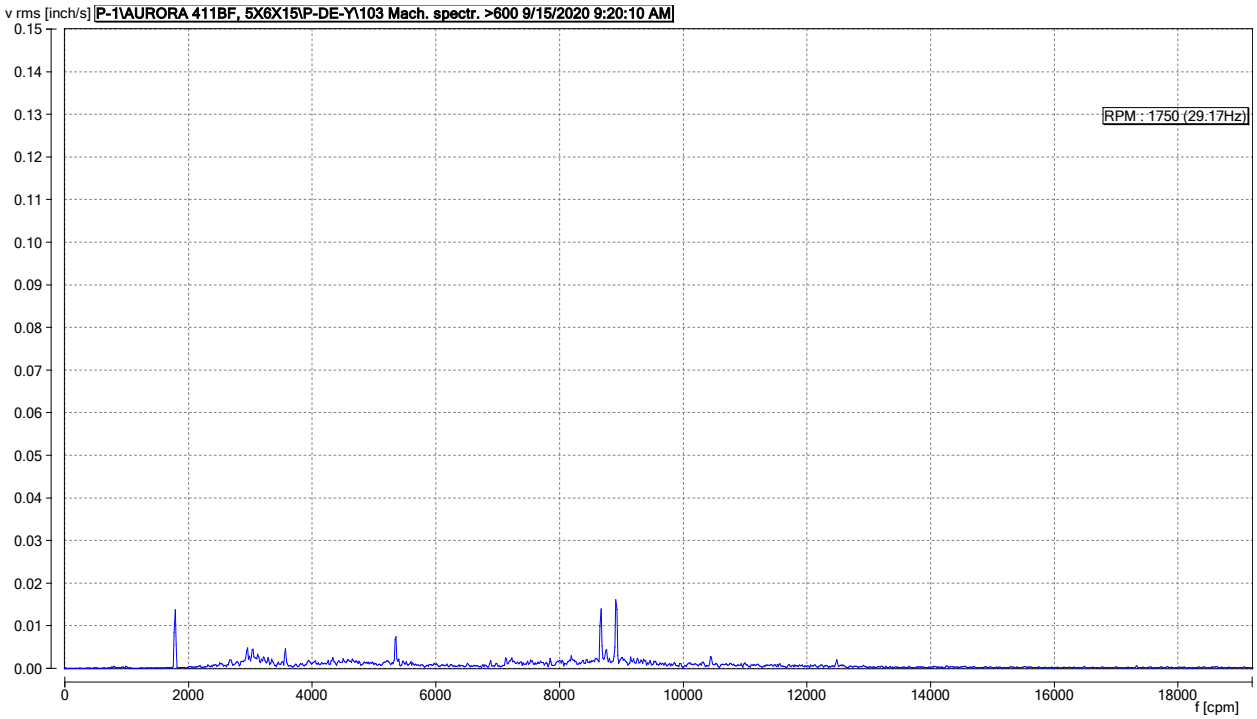

Figure 9: BP-5, P-DE-Y. All peaks are low.

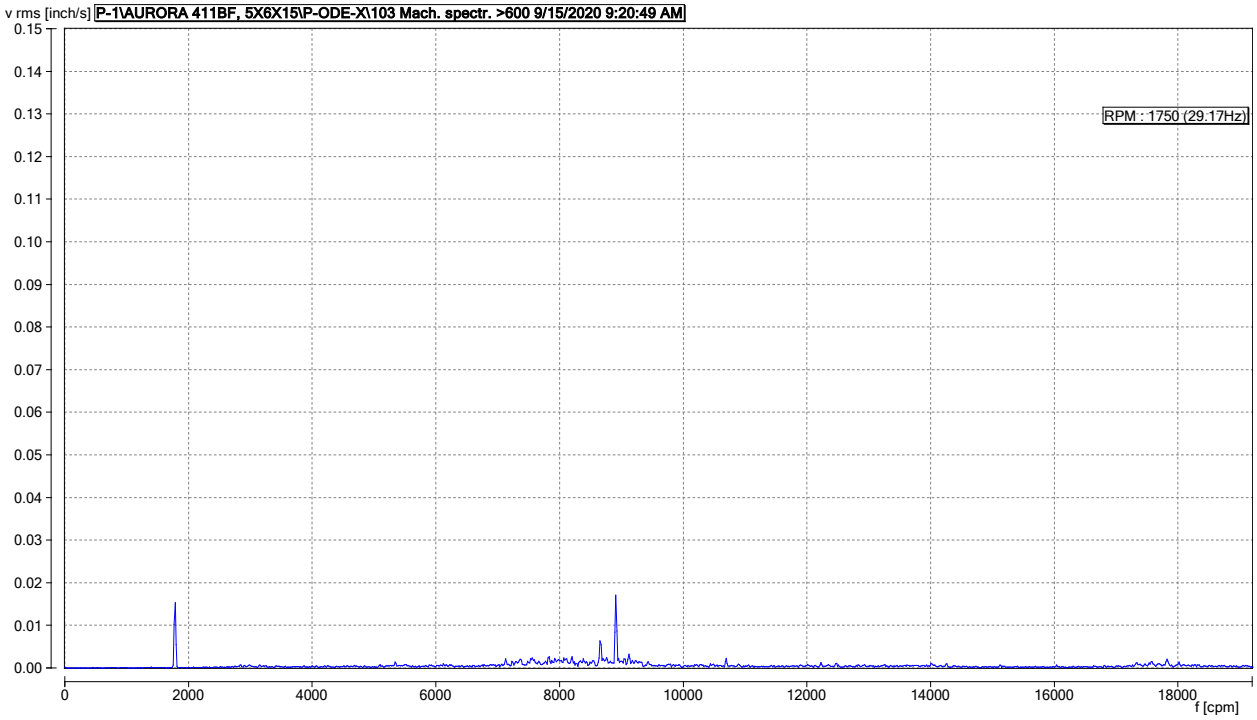

Figure 10: BP-5, P-ODE-X. All peaks are low.

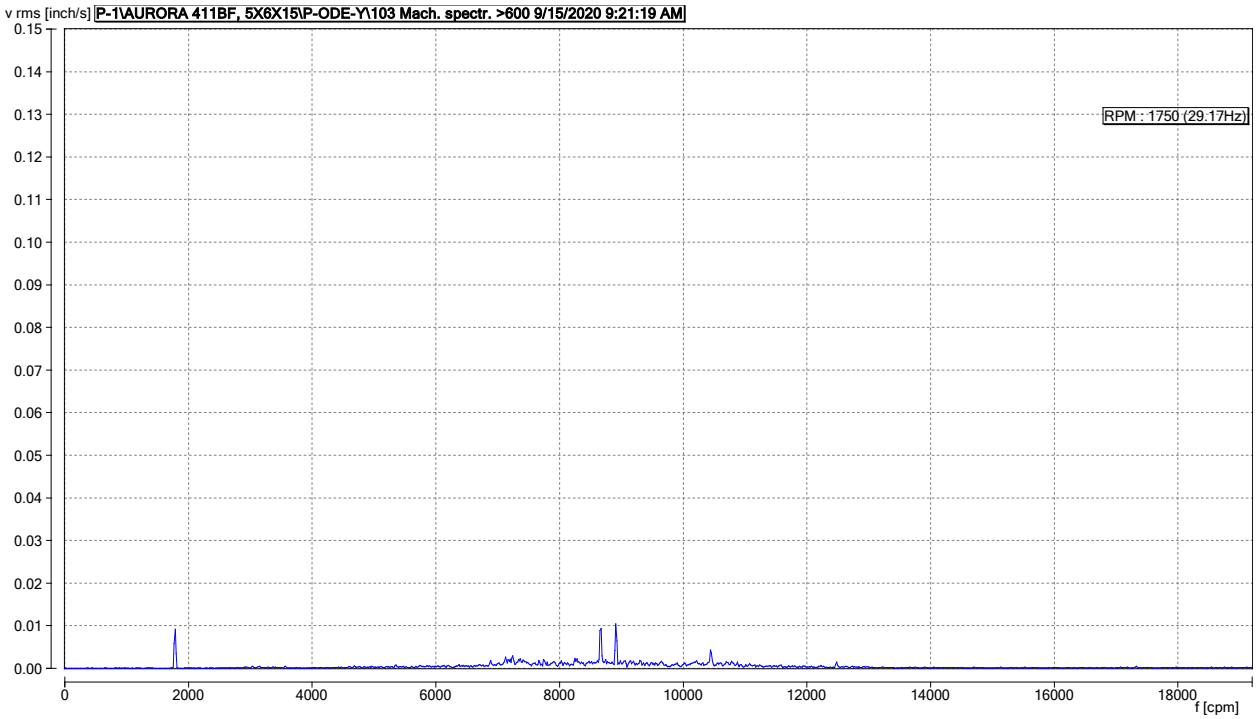

Figure 11: BP-5, P-ODE-Y. All peaks are low.

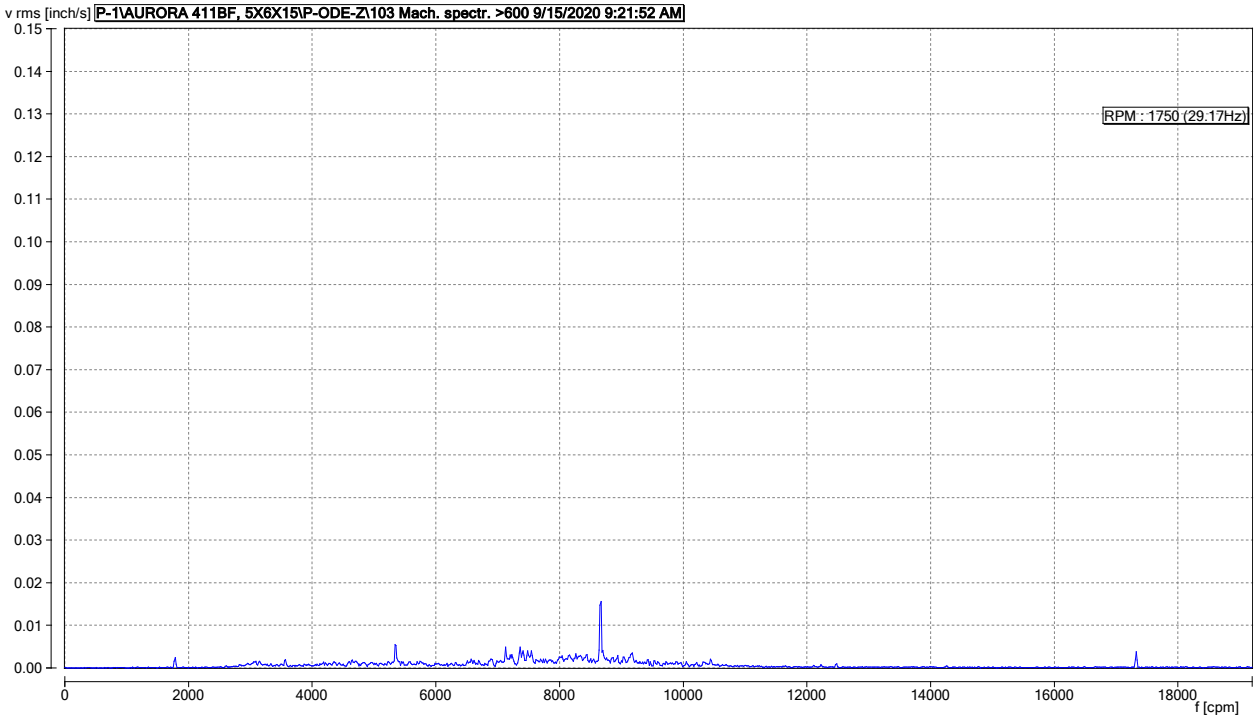

Figure 12: BP-5, P-ODE-Z. All peaks are low.

The overall vibration readings recorded can be found below in Table 1. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 1: BP-5 Overal Vibration - Velocity (in/sec rms)

Time	8:40 AM	9:56 AM	9:12 AM
Speed	1,781	1,781	1,781
POR?	Yes	Yes	Yes
M-ODE-X	0.014	0.022	0.015
M-ODE-Y	0.017	0.019	0.023
M-ODE-Z	0.027	0.027	0.028
M-DE-X	0.017	0.017	0.016
M-DE-Y	0.027	0.027	0.026
P-DE-X	0.039	0.035	0.043
P-DE-Y	0.036	0.036	0.045
P-ODE-X	0.047	0.038	0.044
P-ODE-Y	0.032	0.028	0.031
P-ODE-Z	0.055	0.041	0.044

All vibration readings are well below the HI limits.

TEST DISCUSSIONS

- Hydraulic Operation
  - It is difficult to make any conclusions on performance as the original conditions of service or trim could not be located. An assumed trim level was used which matches the data test points.
  - The pump performs close to the assumed catalog curve.

- Electrical Operation
  - The maximum power recorded was 64 hp, which is above the motor rated power of 60 hp and within the service factor.

- Mechanical Operation
  - The maximum vibration is 0.055 in/sec rms, well below the HI recommended limits.

SUMMARY CONCLUSIONS

BP-5 pump performs close to the assumed catalog curve, but it is difficult to say whether it performs close to the original curve. The pump and motor vibration spectrums and overall values are very low. This unit is operating very well.

TEST RESULTS: BP-6

TEST RESULTS

The composite curve in Figure 13 below shows field data points plotted against the catalog curve.

- Flow Rate
  - Recorded from a rental and Smith Pump's portable strap-on flowmeter
- Total Dynamic Head (TDH)
  - Calculated based on the discharge pressure, wet well level, and discharge velocity head
- Pump Brake Horsepower
  - Measured using a rented 3-phase power quality logger
- Efficiency Curve
  - Calculated from the flow rate, TDH, and pump brake horsepower
  - Calculating the efficiency from field data does not produce very accurate results due to the errors in the flow, pressure, and power measurements from the lack of proper piping arrangements and not having a calibrated motor

Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-01	**Pump Mfg**	Aurora	**Rated Capacity**	[gpm]	1,500	**Tested Date**	9/15/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	[ft of H2O]	145	**Tested By**	Shane Wallace
Plant	Wakeforest Water Plant	**Pump Model**	411, 5x6x15	**Rated Power**	[hp]	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	[rpm]	1,750	**Witnessed By**	
Tag Number	P-6	**Serial Number**	92-16929	**Rated Efficiency**	[%]	Unknownn	**Company**	City of West University Place

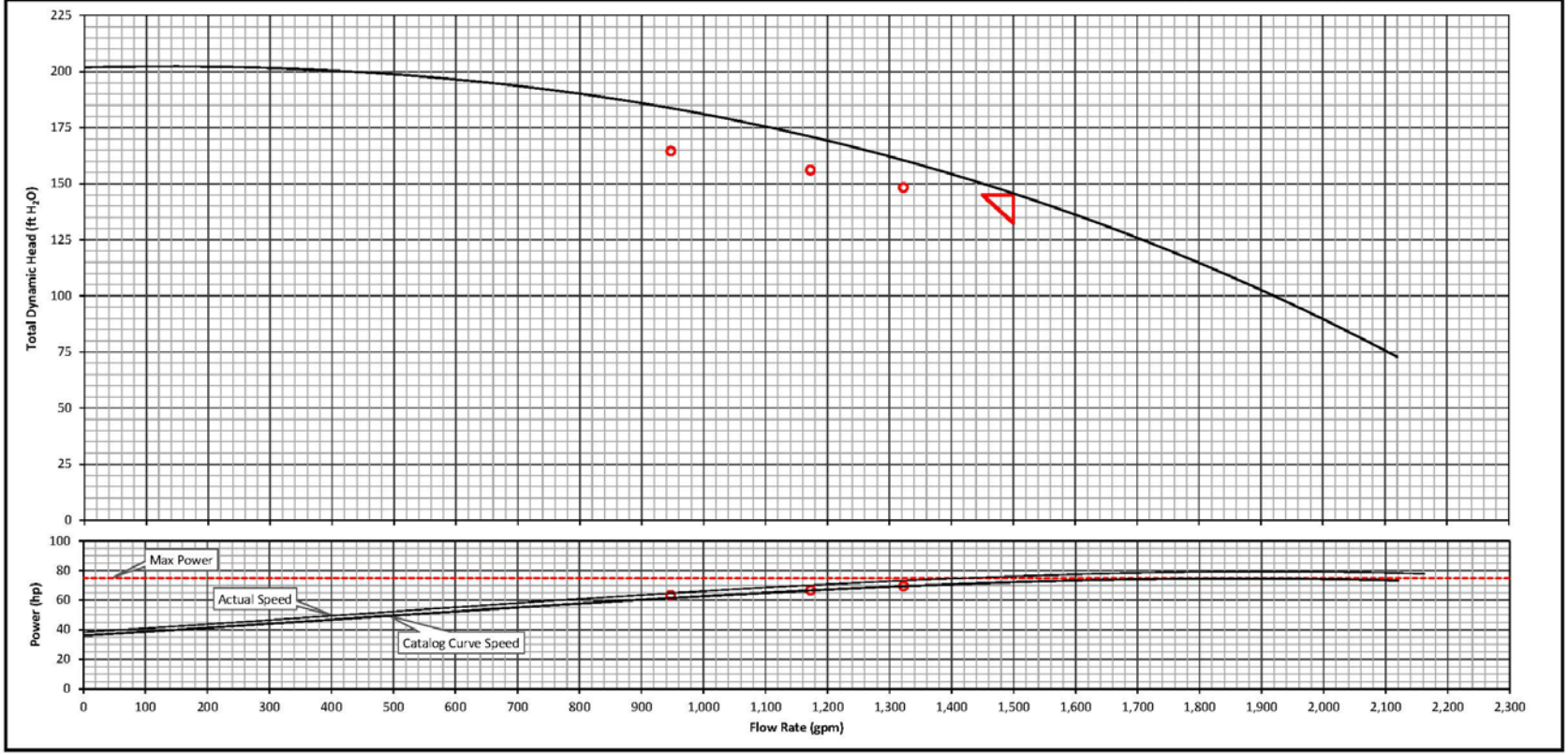

Figure 13: BP-6 Field Test

The pump performance test data (hydraulic and electrical) shows the field test points recorded for BP-6. The instrument values were recorded in concert with one another. The data is reduced to result in the points that show up in the composite curve chart.

The pump rated speed is 1,750 rpm and the motor rated speed is 1,780 rpm. Using the affinity laws, the power will increase by 5% with this speed difference. That maximum power shown on the catalog curve at 1,750 rpm is 74.7 hp but at 1,780 rpm will be 78.6 hp which exceeds the motor rated horsepower. It is recommended to order the pump or new impeller at the motor rated speed to prevent these kinds of issues.

Once the data is collected and reduced to a value for flow, total head, shaft speed, pump brake horsepower, and pump efficiency values, it is then speed corrected to the nominal value using the Affinity Laws. We make this speed correction to overlay the field results on the factory test curves at the same speed the factory tested at.

Vibration Transducer Nomenclature:

M = Motor

P = Pump

ODE = Opposite drive end

DE = Bottom of the motor

X = Perpendicular to the shaft, horizontal

Y = Perpendicular to the shaft, vertical

Z = Axial

cpm = Cycles per minute (somewhat analogous to revolutions per minute)

For example, the vibration on the motor at the opposite end of the coupling and in the horizontal direction would be M-ODE-X.

The spectrums below in Figure 14 to Figure 23 are laid out such that he horizontal axis is the vibration frequency, in cpm, and the vertical axis is the vibration amplitude in velocity units, in/sec rms.

The spectrums on the pump and motor both show bearing outer race defects for the motor bearings, 6313; due to this defect showing up on all locations, it is difficult to determine which motor bearing has this defect. There are also spectral peaks at 5.93X run speed that I have been unable to explain. In the motor Z direction there are peaks at 1X, 2X, and 3X which indicates possible angular misalignment. The pump does not show any spectrums of interest.

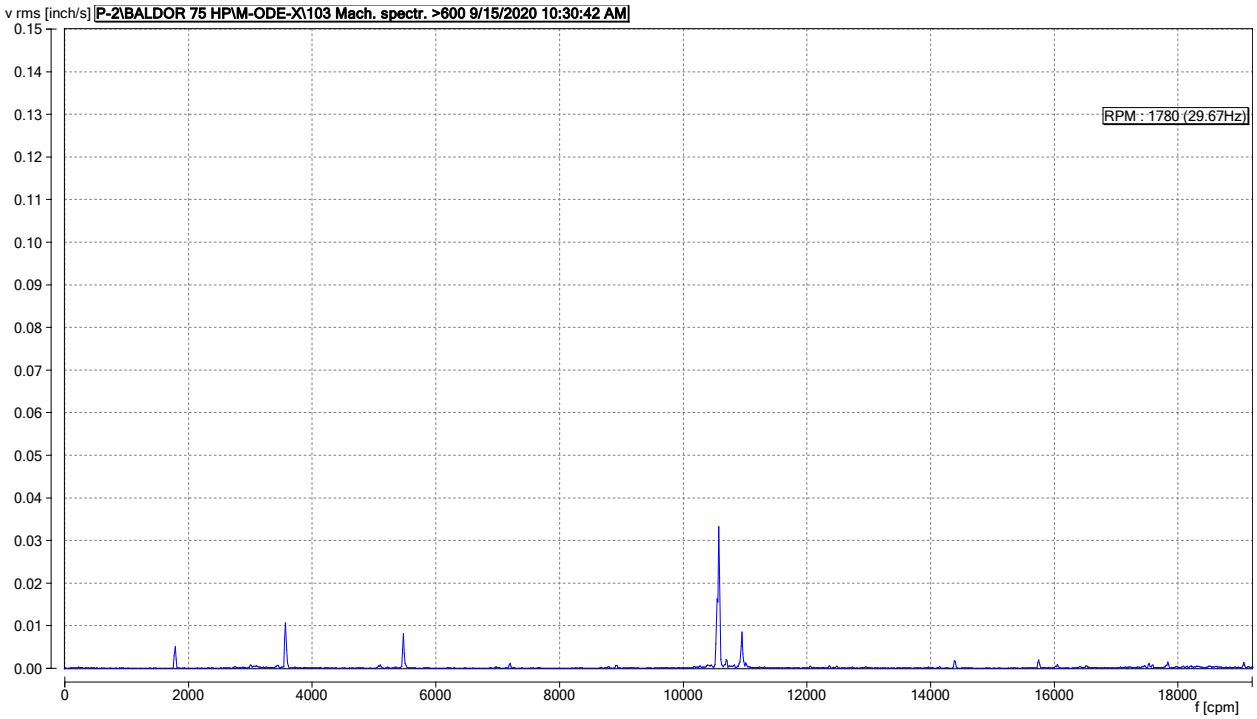

Figure 14: BP-6, M-ODE-X. Maximum peaks are 0.033 in/sec rms at 10,579 cpm (5.93X run speed) and 0.008 in/sec rms at 5,475 cpm (1X bearing out ring defect).

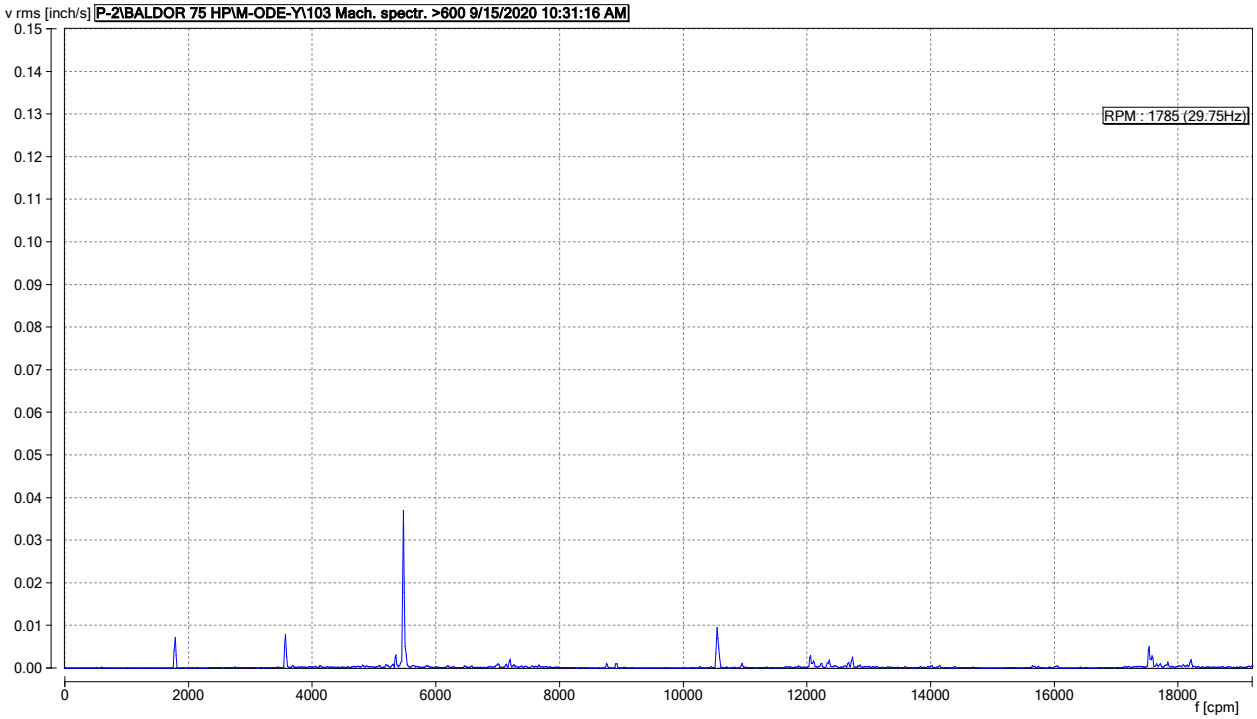

Figure 15: BP-6, M-ODE-Y. Maximum peak is 0.037 in/sec rms at 5,475 cpm (1X bearing outer ring defect).

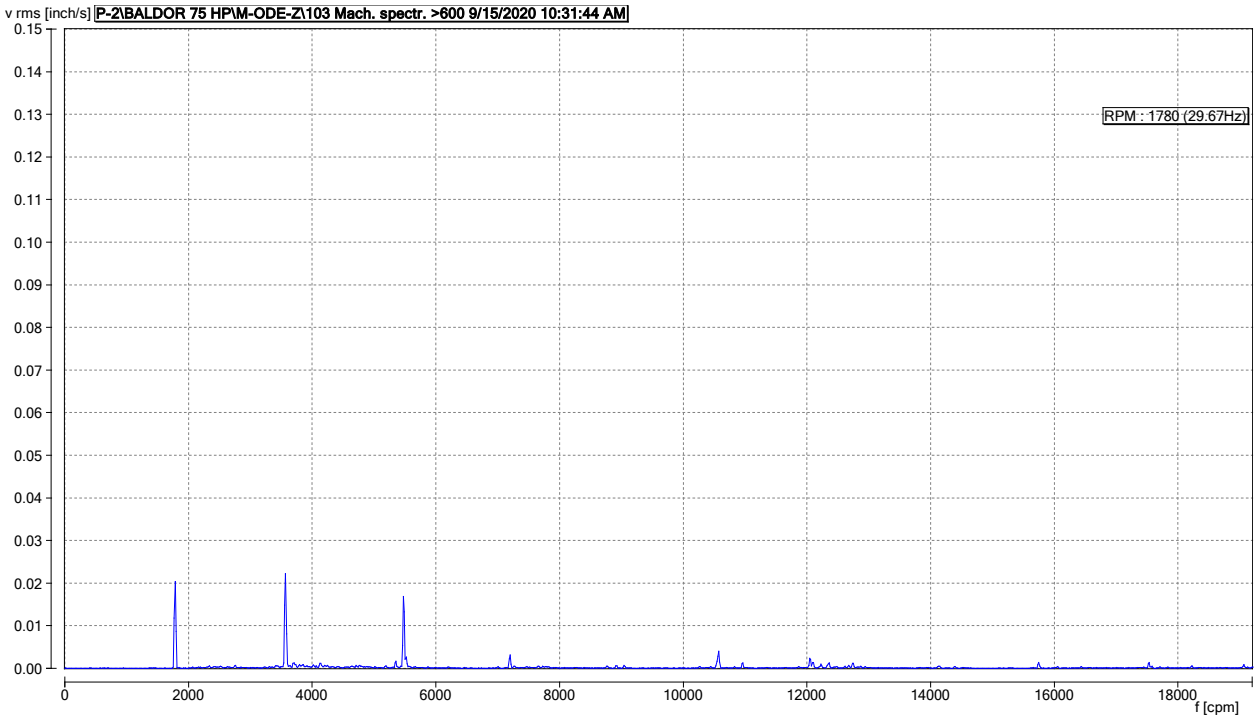

Figure 16: BP-6, M-ODE-Z. Maximum peaks are 0.022 in/sec rms at 3,570 cpm (2X run speed), 0.020 in/sec rms at 1,785 cpm (1X run speed), and 0.017 in/sec rms at 5,478 cpm (1X bearing outer ring defect).

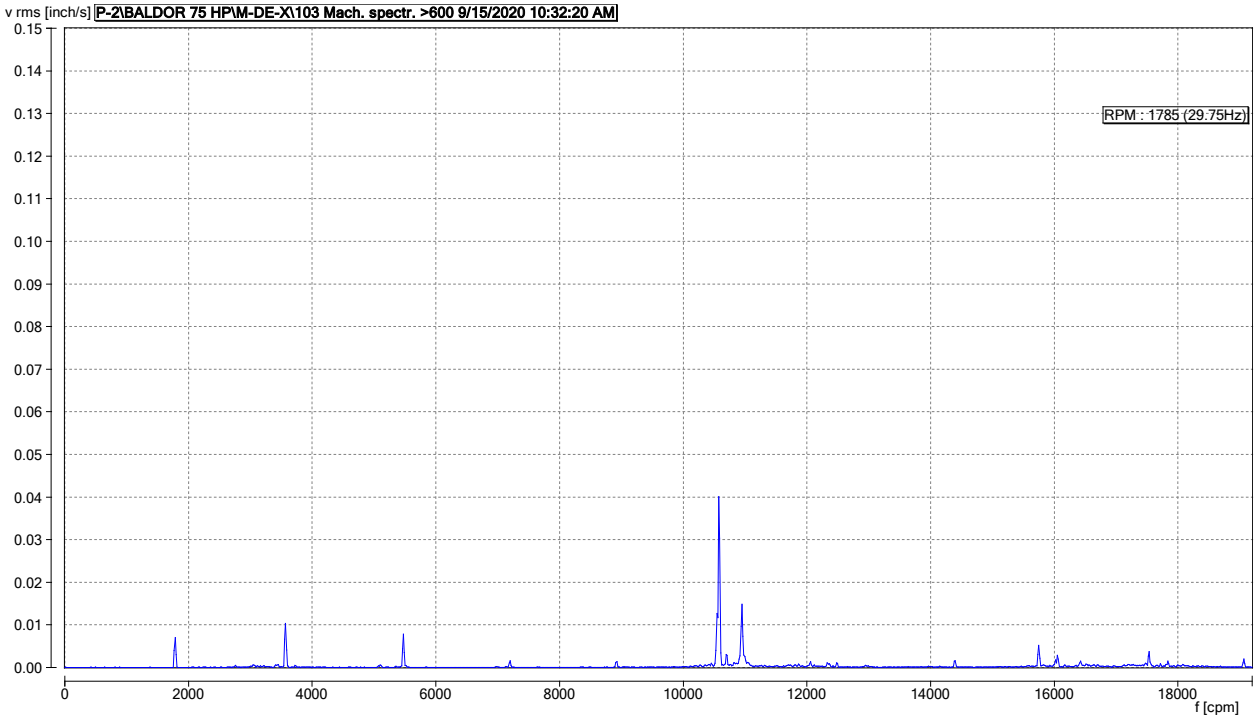

Figure 17: BP-6, M-DE-X. Maximum peaks are 0.040 in/sec rms at 10,579 cpm (5.93X run speed), 0.015 in/sec rms at 10,946 cpm (6.14X run speed), and 0.008 in/sec rms at 5,475 cpm (1X bearing outer ring defect).

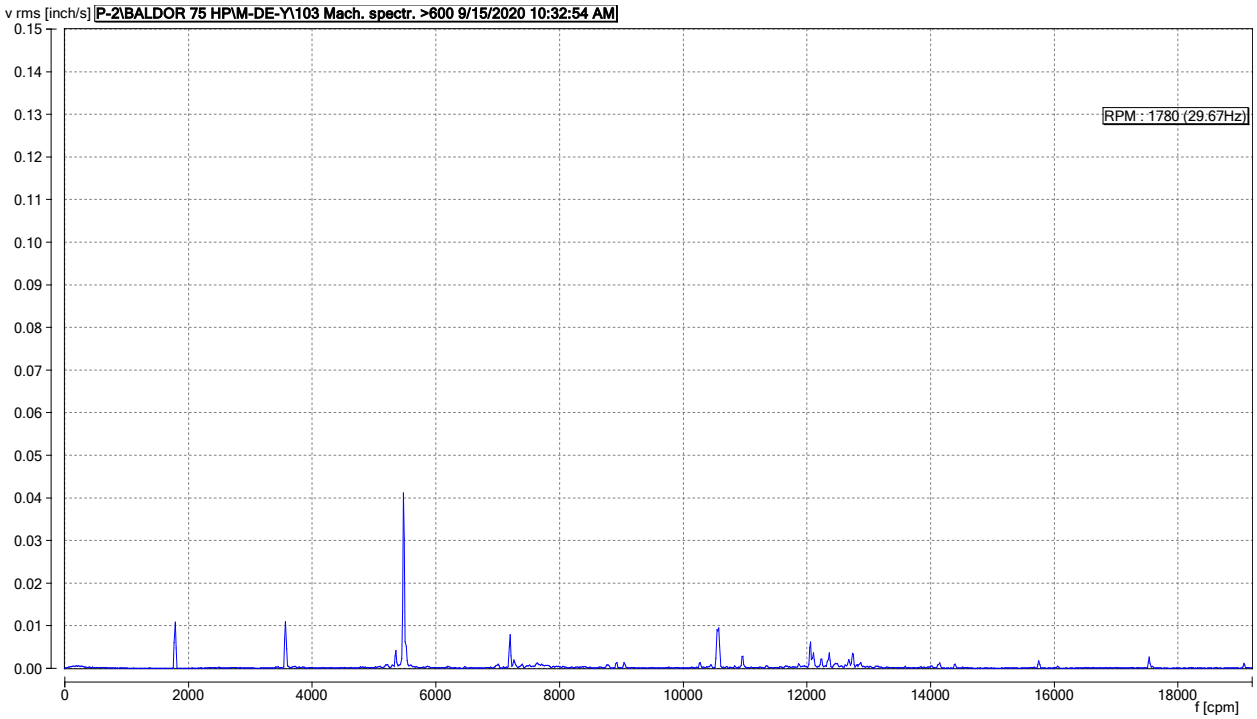

Figure 18: BP-6, M-DE-Y. Maximum peak is 0.041 in/sec rms at 5,479 cpm (1X bearing outer ring defect).

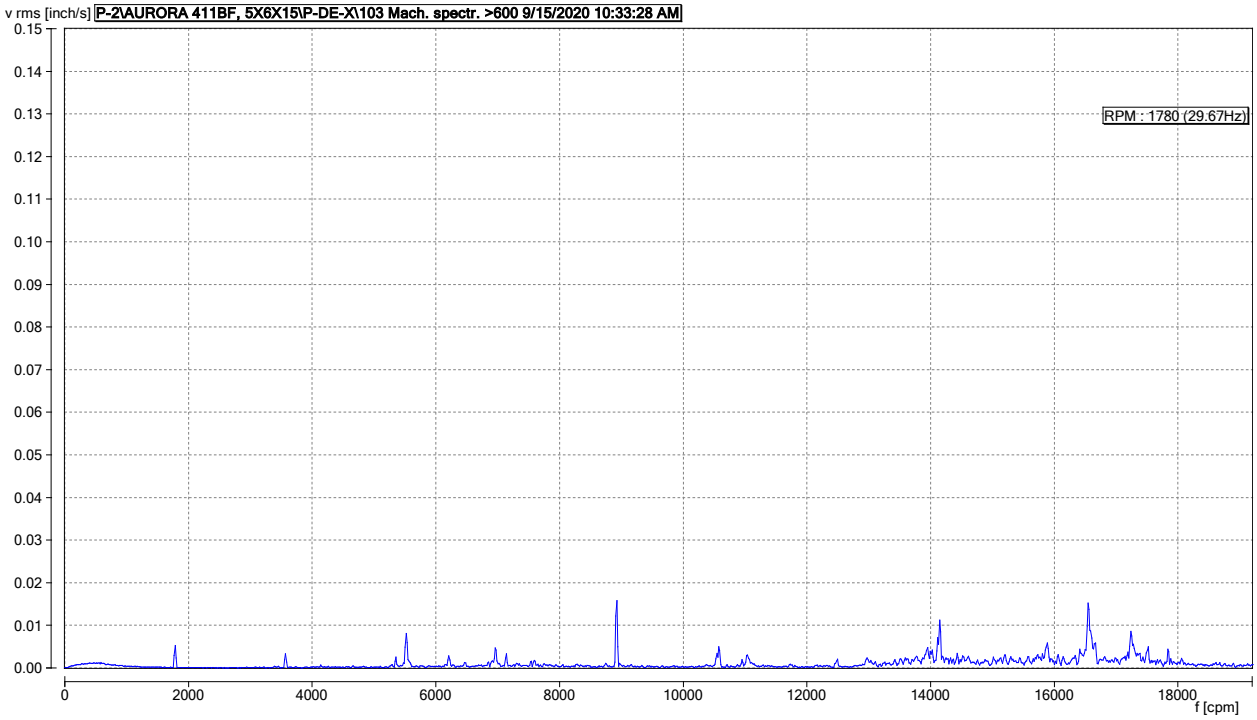

Figure 19: BP-6, P-DE-X. Maximum peaks are 0.022 in/sec rms at 8,925 cpm (5X run speed) and 0.022 in/sec rms at 16,549 cpm (3X bearing outer race defect).

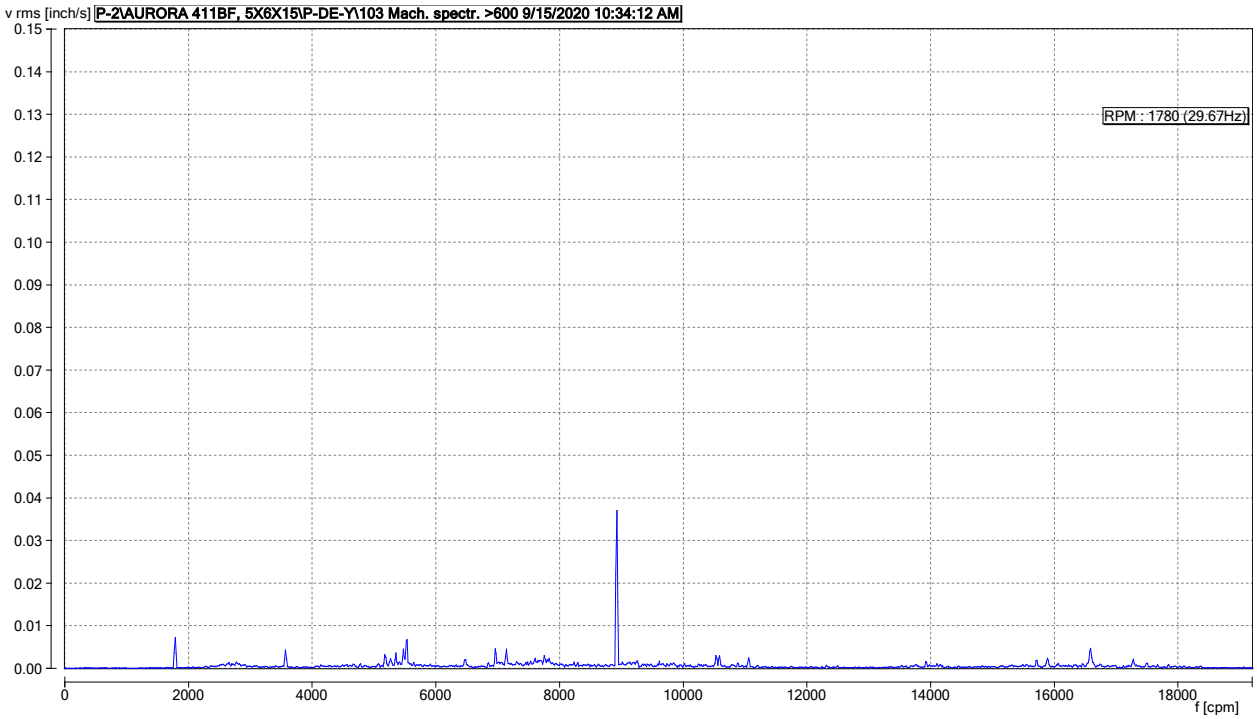

Figure 20: BP-6, P-DE-Y. Maximum peak is 0.037 in/sec rms at 8,921 cpm (5X run speed).

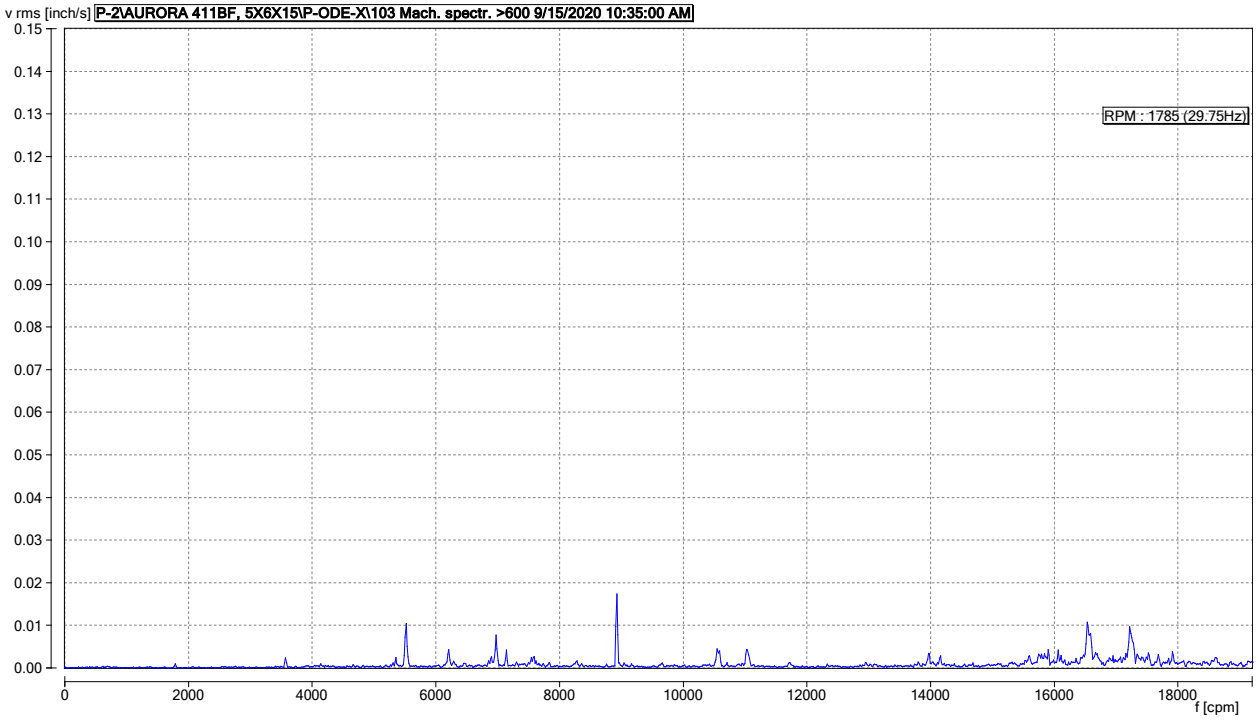

Figure 21: BP-6, P-ODE-X. Maximum peak is 0.017 in/sec rms at 8,925 cpm (5X run speed).

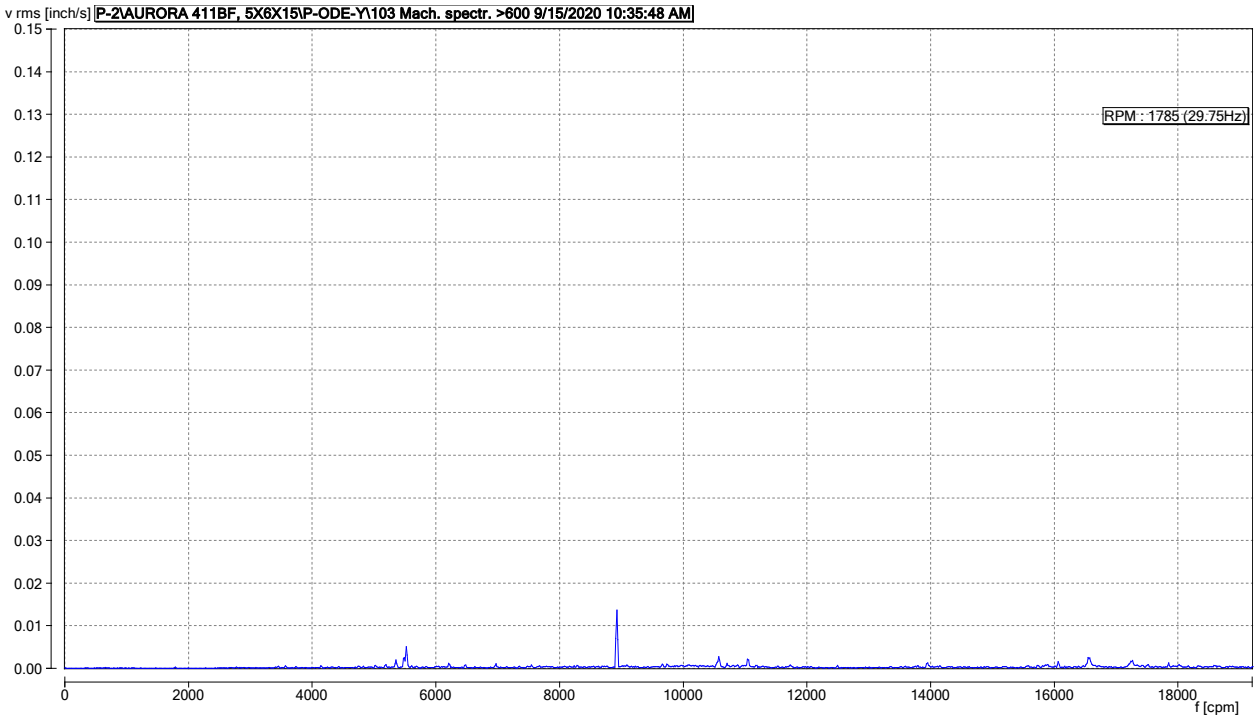

Figure 22: BP-6, P-ODE-Y. Maximum peak is 0.017 in/sec rms at 8,925 cpm (5X run speed).

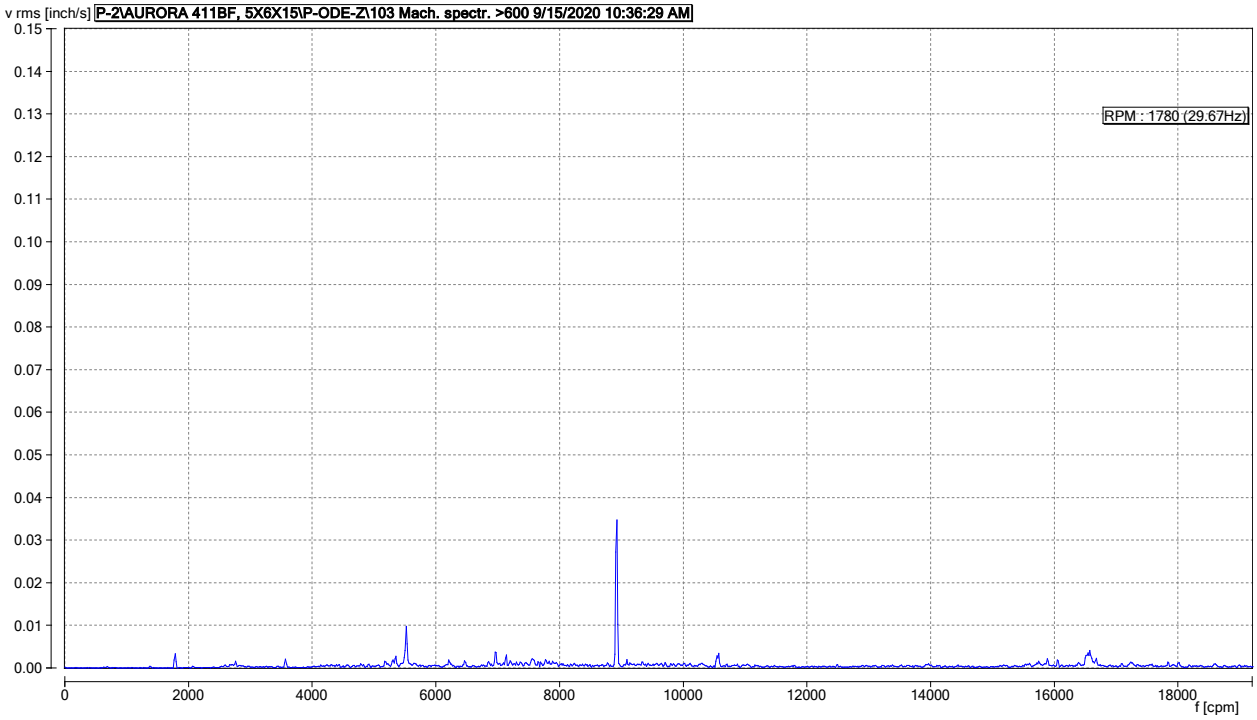

Figure 23: BP-6, P-ODE-Z. Maximum peak is 0.035 in/sec rms at 8,921 cpm (5X run speed).

The overall vibration readings recorded can be found below in Table 2. The overall velocity limits are set by Hydraulic Institute 9.6.4.2.5.1a to be 0.15 in/sec rms within the preferred operating range (POR) and 0.20 in/sec rms within the allowable operating range (AOR) but outside of the POR.

Table 2: BP-6 Overal Vibration - Velocity (in/sec rms)

Time	9:52 AM	10:08 AM	10:28 AM
Speed	1,785	1,785	1785
POR?	Yes	Yes	Yes
M-ODE-X	0.052	0.057	0.042
M-ODE-Y	0.048	0.046	0.045
M-ODE-Z	0.043	0.044	0.042
M-DE-X	0.057	0.057	0.054
M-DE-Y	0.055	0.052	0.054
P-DE-X	0.040	0.069	0.088
P-DE-Y	0.052	0.048	0.051
P-ODE-X	0.076	0.134	**0.154**
P-ODE-Y	0.031	0.033	0.035
P-ODE-Z	0.081	0.095	0.122

The overall vibration readings at the pump opposite drive end either slightly exceeded or almost exceed the HI vibration limits.

TEST DISCUSSIONS

- Hydraulic Operation
  - The pump appears to operate fairly close to the catalog curve. It is likely Smith Pump's strap on flow meter deviated as the flow decreased which is what was seen with BP-5.

- Electrical Operation
  - The maximum power recorded was 74 hp, below the motor rated power of 75 hp.
  - If the pump catalog curve is speed corrected to the motor speed, the motor horsepower will be exceeded when the flow rate exceeds ~1,440 gpm.

- Mechanical Operation
  - The maximum vibration is 0.154 in/sec rms, slightly above the HI recommended limits.
  - The motor vibration seems shows a potential bearing fault and a puzzling peak at 5.93X run speed which does not seem to correlate to any bearing or normal cause. The pump vibration appears to be caused by a raised floor at high frequency which is a potential bearing issue.

SUMMARY CONCLUSIONS

BP-6 motor vibration signatures show a bearing outer race defect, but it is difficult to determine which motor bearing has the issue. There is also a peak at 5.93X which does not line up with a bearing fault or any other normal faults. The pump spectrums do not show any significant issues, but it appears that the overall vibration levels are high due to a raised noise floor at the higher frequencies; this is potentially a bearing issue. The pump operates fairly close to the catalog curve. It is recommended the pump and motor be monitored to ensure the vibration levels and bearing faults do not increase in severity.

APPENDICES

ITEM	DATE	DOCUMENT DESCRIPTION
APPENDIX A	09/15/2020	BP-5 Field Test Data
	09/15/2020	BP-6 Field Test Data

APPENDIX A

FIELD TESTING DATA

SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	Baldor	**PUMP:**	Aurora 411BF, 5x6x15
SERIAL NO.:	09-05380-8/2-02	**SERIAL NO.:**	89-02378
RATED HP:	60 hp	**RATED FLOW:**	Unknown
RATED SPEED:	1,775 rpm	**RATED HEAD:**	Unknown
FLA:	73 A	**RATED SPEED:**	1,750 rpm

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/15/2020	**PLANT:**	Wakeforest Water Plant
PROJECT #:	179004-01	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-5
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 8:35 AM STOP:

	TIME:	8:40 AM	8:56 AM	9:12 AM	9:12 AM						
	RUN TIME (MIN):	5	21	37	37						
	FLOW METER 1: (GPM)	1,263.00	1,400.00	898.00	1,040.00						
	FLOW RATE (GPM):	1,263	1,400	898	1,040						
	SUCT. CORRECTION (FT):	0.00	0.00	0.00	0.00						
	SUCTION DIAMETER (IN):	6.00	6.00	6.00	6.00						
	SUCT. PRESSURE: (PSI)	9.99	9.82	10.11	10.11						
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):	3.19	3.92	1.61	2.16						
	DISCH. CORRECTION (FT):	1.00	1.00	1.00	1.00						
	DISCH. DIAMETER (IN):	5.00	5.00	5.00	5.00						
	DISCH. PRESSURE: (FT)	137.00	144.50	163.00	163.00						
	DISCH. VELOCITY HEAD (FT):	6.61	8.12	3.34	4.48						
	HEAD LOSS (FT):	0.00	0.00	0.00	0.00						
	TDH (FT):	118.3	127.0	142.4	143.0						
	SPEED (RPM):	1,781	1,781	1,781	1,781						
	VOLTAGE A-B (V):	490.2	490.8	489.3	489.3						
	VOLTAGE B-C (V):	492.5	492.6	491.3	491.3						
	VOLTAGE A-C (V):	492.0	492.1	490.9	490.9						
	VOLTAGE IMBALANCE (%):	0.3	0.2	0.2	0.2						
	CURRENT A-B (AMPS):	74.6	73.2	69.6	69.6						
	CURRENT B-C (AMPS):	73.7	72.6	68.8	68.8						
	CURRENT A-C (AMPS):	74.9	73.3	69.8	69.8						
	CURRENT IMBALANCE (%):	0.9	0.6	0.8	0.8						
	POWER FACTOR:	0.82	0.81	0.81	0.81						
	INPUT POWER (kW):	51.6	50.5	47.7	47.7						
	MOTOR EFF. (%):	92.4%	92.4%	92.4%	92.4%						
	SHAFT POWER (HP):	64	63	59	59						
SPEED CORRECTED	**TARGET SPEED (RPM):**	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775	1,775
SPEED CORRECTED	**FLOW RATE (GPM):**	1,259	1,395	895	1,036						
SPEED CORRECTED	**TDH (FT):**	117.5	126.2	141.4	142.0						
SPEED CORRECTED	**POWER (HP):**	63.3	61.9	58.4	58.4						
SPEED CORRECTED	**PUMP EFF. (%):**	59.0	71.8	54.7	63.6						
SPEED CORRECTED	**WIRE TO WATER EFF (%):**	54.5	66.3	50.5	58.8						
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**	0.027	0.027	0.028							
VIBRATION (IN/SEC RMS)	**M-NDE-X (90°):**	0.014	0.022	0.015							
VIBRATION (IN/SEC RMS)	**M-NDE-Y (0°):**	0.017	0.019	0.023							
VIBRATION (IN/SEC RMS)	**M-DE-X (90°):**	0.017	0.017	0.016							
VIBRATION (IN/SEC RMS)	**M-DE-Y (0°):**	0.027	0.027	0.026							
VIBRATION (IN/SEC RMS)	**P-DE-X (90°):**	0.039	0.035	0.043							
VIBRATION (IN/SEC RMS)	**P-DE-Y (0°):**	0.036	0.036	0.045							
VIBRATION (IN/SEC RMS)	**P-NDE-X (90°):**	0.047	0.038	0.044							
VIBRATION (IN/SEC RMS)	**P-NDE-Y (0°):**	0.032	0.028	0.031							
VIBRATION (IN/SEC RMS)	**P-NDE-AXIAL:**	0.055	0.041	0.044							

NOTES:

1 - Approximate 1 minute flow rate from the station totalizer flow meter showed 1,040 gpm for the fourth point (9:12 AM)

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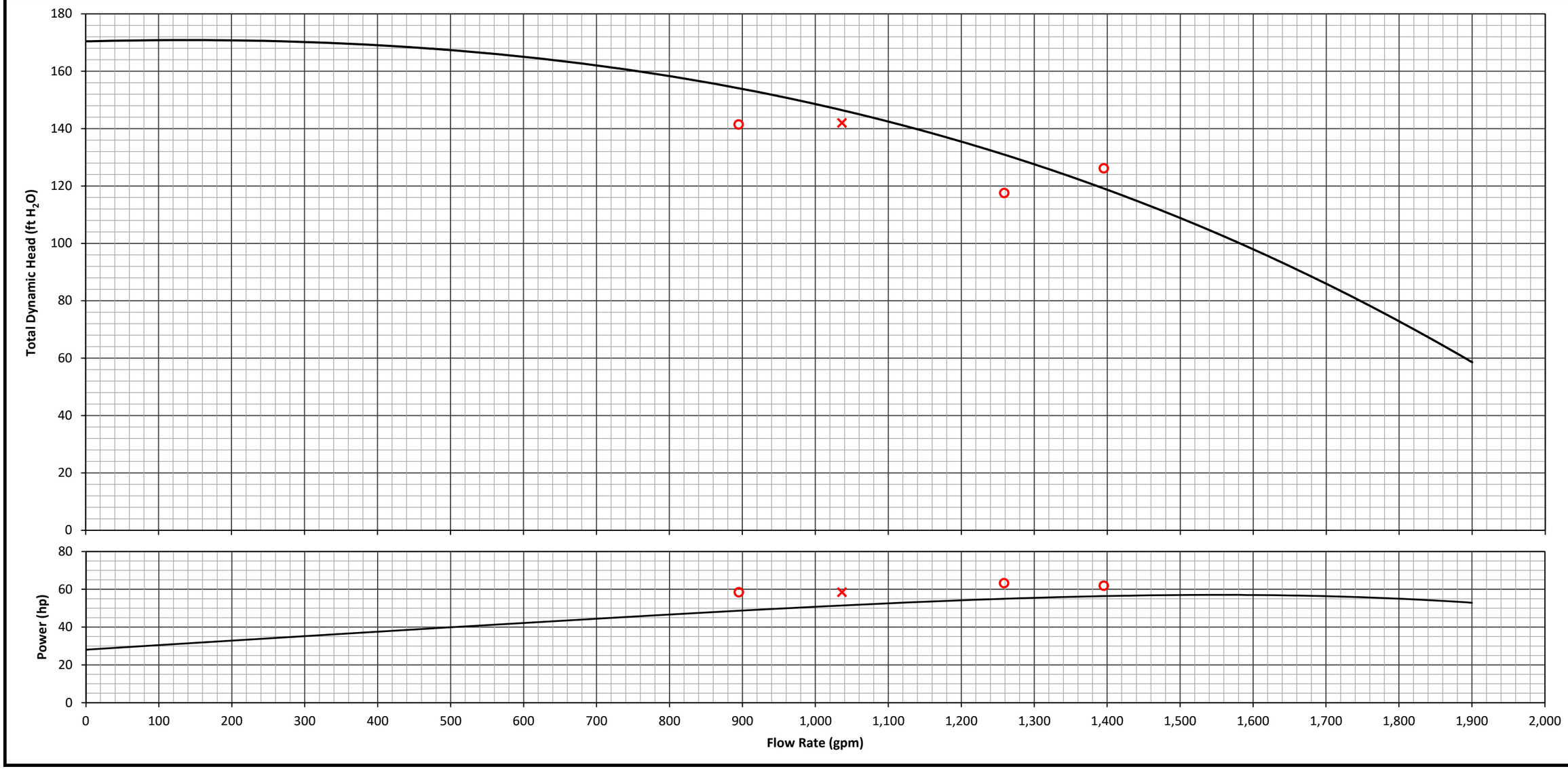
Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-01	**Pump Mfg**	Aurora	**Rated Capacity**	**[gpm]**	Unknownn	**Tested Date**	9/15/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	Unknownn	**Tested By**	Shane Wallace
Plant	Wakeforest Water Plant	**Pump Model**	411, 5x6x15	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	1,775	**Witnessed By**	
Tag Number	P-5	**Serial Number**	89-02378	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



SMITH PUMP COMPANY, INC.

NAMEPLATE DATA

MOTOR:	Baldor, EM4316TS	**PUMP:**	Aurora 411BF, 5x6x15
SERIAL NO.:	A1208072074	**SERIAL NO.:**	92-16929
RATED HP:	75 hp	**RATED FLOW:**	1,500 gpm
RATED SPEED:	1,780 rpm	**RATED HEAD:**	145' TDH
FLA:	85.9 A	**RATED SPEED:**	1,750 rpm

TEST DATA

BY:	Shane Wallace	**END USER:**	City of West University Place
DATE:	9/15/2020	**PLANT:**	Wakeforest Water Plant
PROJECT #:	179004-01	**PUMP STATION:**	Booster PS
ENGINEER:	Freese & Nichols	**PUMP TAG #:**	P-6
CONTRACTOR:	N/A	**STATIC HEAD (FT):**	

START: 9:40 AM STOP:

	TIME:	9:52 AM	10:08 AM	10:28 AM							
	RUN TIME (MIN):	12	28	48							
	FLOW METER 1: **(GPM)**	1,349.00	1,196.00	966.00							
	FLOW RATE (GPM):	1,349	1,196	966							
	SUCT. CORRECTION (FT):	0.00	0.00	0.00							
	SUCTION DIAMETER (IN):	6.00	6.00	6.00							
	SUCT. PRESSURE: **(PSI)**	8.91	9.40	10.78							
	WET WELL LEVEL (FT):										
	SUCT. VELOCITY HEAD (FT):	3.64	2.86	1.86							
	DISCH. CORRECTION (FT):	1.00	1.00	1.00							
	DISCH. DIAMETER (IN):	5.00	5.00	5.00							
	DISCH. PRESSURE: **(FT)**	170.00	180.00	193.00							
	DISCH. VELOCITY HEAD (FT):	7.54	5.93	3.87							
	HEAD LOSS (FT):	0.00	0.00	0.00							
	TDH (FT):	154.3	162.4	171.1							
	SPEED (RPM):	1,785	1,785	1,785							
	VOLTAGE A-B (V):	488.9	483.7	483.5							
	VOLTAGE B-C (V):	489.6	484.5	483.9							
	VOLTAGE A-C (V):	487.6	482.9	482.6							
	VOLTAGE IMBALANCE (%):	0.2	0.2	0.2							
	CURRENT A-B (AMPS):	81.1	78.9	75.3							
	CURRENT B-C (AMPS):	82.9	80.5	76.4							
	CURRENT A-C (AMPS):	79.7	77.9	74.0							
	CURRENT IMBALANCE (%):	2.1	1.8	1.6							
	POWER FACTOR:	0.84	0.84	0.83							
	INPUT POWER (kW):	57.7	55.5	52.4							
	MOTOR EFF. (%):	95.4%	95.4%	95.4%							
	SHAFT POWER (HP):	74	71	67							
SPEED CORRECTED	**TARGET SPEED (RPM):**	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
	FLOW RATE (GPM):	1,323	1,173	947							
	TDH (FT):	148.3	156.1	164.5							
	POWER (HP):	69.5	66.8	63.2							
	PUMP EFF. (%):	71.3	69.1	62.3							
	WIRE TO WATER EFF (%):	68.0	66.0	59.4							
VIBRATION (IN/SEC RMS)	**M-NDE-AXIAL:**	0.043	0.044	0.042							
	M-NDE-X (90°):	0.052	0.057	0.042							
	M-NDE-Y (0°):	0.048	0.046	0.045							
	M-DE-X (90°):	0.057	0.057	0.054							
	M-DE-Y (0°):	0.055	0.052	0.054							
	P-DE-X (90°):	0.040	0.069	0.088							
	P-DE-Y (0°):	0.052	0.048	0.051							
	P-NDE-X (90°):	0.076	0.134	0.154							
	P-NDE-Y (0°):	0.031	0.033	0.035							
	P-NDE-AXIAL:	0.081	0.095	0.122							

NOTES:

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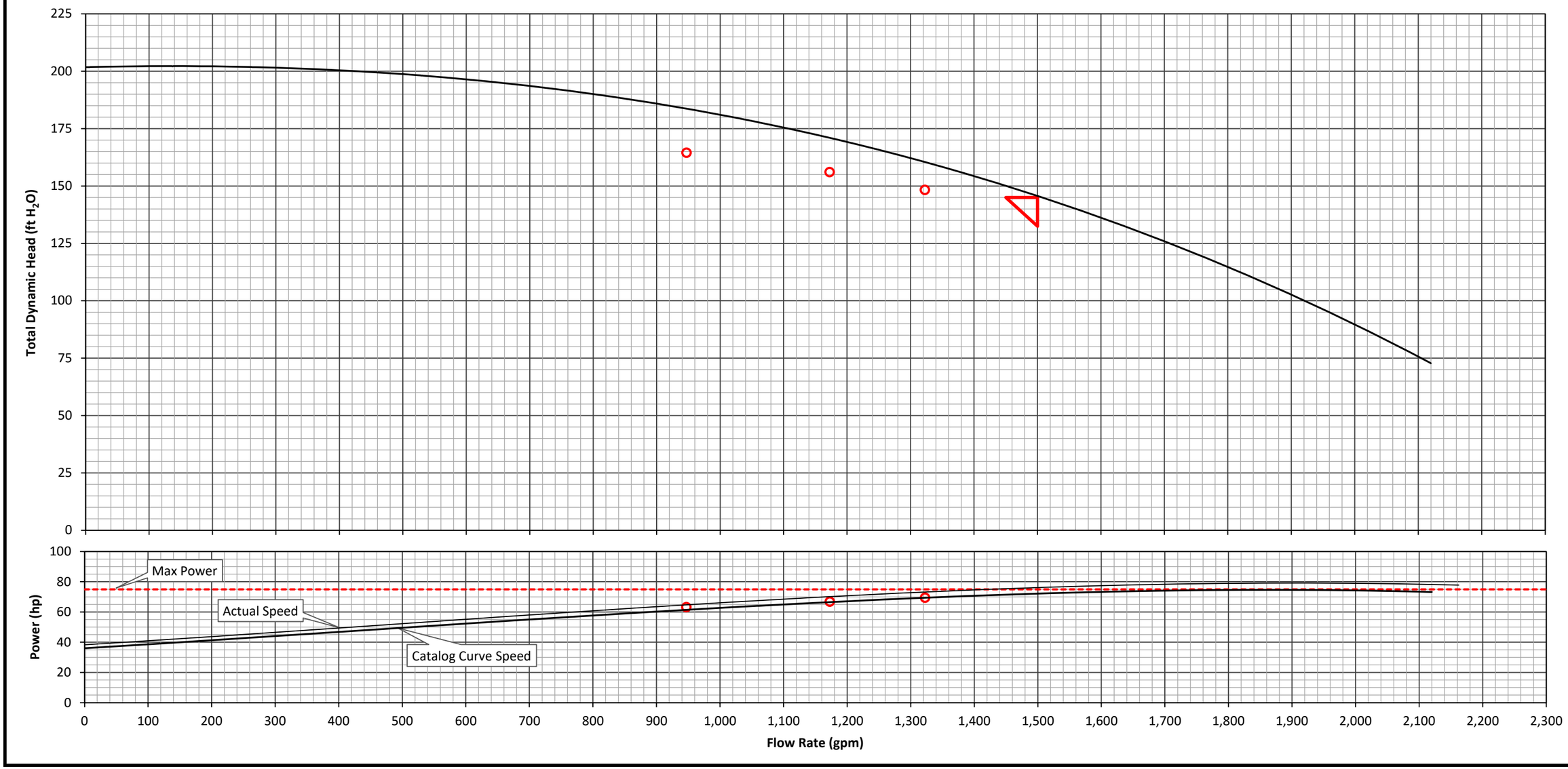
Smith Pump Company, Inc.
Pump & Pumping Systems Specialists since 1962

FIELD PERFORMANCE TEST

Project Number	179004-01	**Pump Mfg**	Aurora	**Rated Capacity**	**[gpm]**	1,500	**Tested Date**	9/15/2020
End User	City of West University Place	**Pump Type**	HSC	**Rated TDH**	**[ft of H2O]**	145	**Tested By**	Shane Wallace
Plant	Wakeforest Water Plant	**Pump Model**	411, 5x6x15	**Rated Power**	**[hp]**	Unknownn	**Company**	Smith Pump Co
Pump Station	Booster PS	**Number of Stages**	1	**Rated Speed**	**[rpm]**	1,750	**Witnessed By**	
Tag Number	P-6	**Serial Number**	92-16929	**Rated Efficiency**	**[%]**	Unknownn	**Company**	City of West University Place



APPENDIX F
Hydraulic Model Development & Calibration

FREESE AND NICHOLS
Innovative approaches
Practical results
Outstanding service

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1.0 MODEL DEVELOPMENT AND CALIBRATION

As part of this study, a hydraulic model of the City's water system was developed to analyze and evaluate the City's distribution system. The model utilizes InfoWater® hydraulic modeling software by Innovyze, which makes use of engineering equations and mathematical algorithms to determine the flows and pressures that would occur in a distribution system under a specified set of conditions. The hydraulic water model was created utilizing the City's GIS files, inventory information, and information collected during field testing. A screenshot of the hydraulic model is shown on **Figure 1-1.**

Figure 1-1: West University Place's Hydraulic Water Model

1.1 MODELED INFRASTRUCTURE

1.1.1 Water Lines and Junctions

All water mains in the City's GIS were included in the hydraulic model. The model contains approximately 58 miles or 2,551 links of water line. Information such as material and installation year were preserved from the City's GIS where data was available and input into the hydraulic model. Water lines were assigned initial Hazen-Williams roughness coefficients of 110.

There are also 2,289 junctions in the model. Junctions are placed where modeled pipes connect and are utilized to store demand data. All junctions in the distribution system were assigned an elevation based on LiDAR data.

1.1.2 Pumping and Storage Facilities

There are six pumps, four storage tanks, and two reservoirs in the model, representing groundwater wells. Within the hydraulic model, multiple ground storage tanks at each water plant were simulated by a single tank that maintains the onsite height and total storage volume. Tank elevations were assigned using survey data, as-built information, and LiDAR. All pumping and storage facilities were manually added to the model based on as-built drawings and information provided by the City. Tested pump curves were input into the model for all booster pumps. Variable area tank curves were developed for ESTs based on tank shapes to accurately model changes in volume.

1.1.3 Unique IDs

The City's GIS did not have a unique identifier (ID) for each distribution system component. Unique IDs are required by modeling software and are a best practice for maintaining and updating utility system assets in a GIS database. FNI created and assigned unique IDs for all modeled water mains and facilities during the model development process. The format of the assigned unique IDs is shown in **Table 1-1.**

Table 1-1: Format of Unique IDs for Water Distribution System Components

Water System Component	Unique ID Format	Example
Water Main	WU_1234	WU_0223
Storage Tank	Name_EST_Size	Bellaire_EST_0.25MG
Well	Water Plant_Well	Wakeforest_Well
Pump	Water Plant_PMP_1	Milton_PMP_1

1.2 CONNECTIVITY UPDATES

During the model building process, FNI coordinated with IDS on updating the connectivity of the GIS network. IDS provided GIS shapefiles for water lines and valves and updated the connectivity of the lines with available data. FNI further updated the connectivity at hydrant connections, at locations where water lines ended at another line, or where water lines would otherwise be completely disconnected from the rest of the system.

At locations where the connectivity of a line was updated by FNI, the line received a unique ID with the format 'P1234.' The original ID of the line that corresponds to GIS was preserved in the 'Description' field in the model.

1.3 DEMAND ALLOCATION

The distribution, or allocation, of water demands is a crucial step in building a hydraulic model. The spatial location and relative magnitude of demands significantly impact the hydraulics of a water distribution system. FNI allocated demands to the model utilizing water meter billing data. The active water meters were spatially located through a process called geocoding, and the associated consumption was assigned to the nearest model node. Based on the West University's Subdivision and Zoning map shown on **Figure 1-2** and information on meter types from the City's customer billing database, the water demands were divided into eight (8) categories:

- Residential SF-1
- Residential SF-2
- Residential SF-3
- Townhouse District
- Commercial
- Commercial Irrigation
- Residential Irrigation

1.4 MODEL CALIBRATION

In order to verify that the hydraulic model accurately represents West University Place's distribution system, an extended period simulation (EPS) model calibration was performed. The calibration process involves adjusting system operational parameters and roughness values to match a known system condition. August 19, 2020 was selected for a 24-hour calibration. This day was selected as it was a weekday with no rainfall and the system operation was typical with no major changes in pressure due to line breaks or other incidents visible in the pressure recorder data.

FIGURE 1-2

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT

SUBDIVISIONS AND ZONING

LEGEND

- Commercial
- First General Residential GR-1
- PDD - Bellaire Office District
- PDD - TH 1
- PDD - TH 2
- PDD TH-1
- PPD - SF 1
- PPD - TH 3
- PPD - TH 5
- Park in SF District
- Residential SF-1
- Residential SF-2
- Residential SF-3
- Second General Residential GR-2
- Town Center Commercial
- Townhouse District
- Unknown
- Road
- Railroad
- City Limit
- Other City Limit

City of West University Place

FREESE AND NICHOLS

0 900

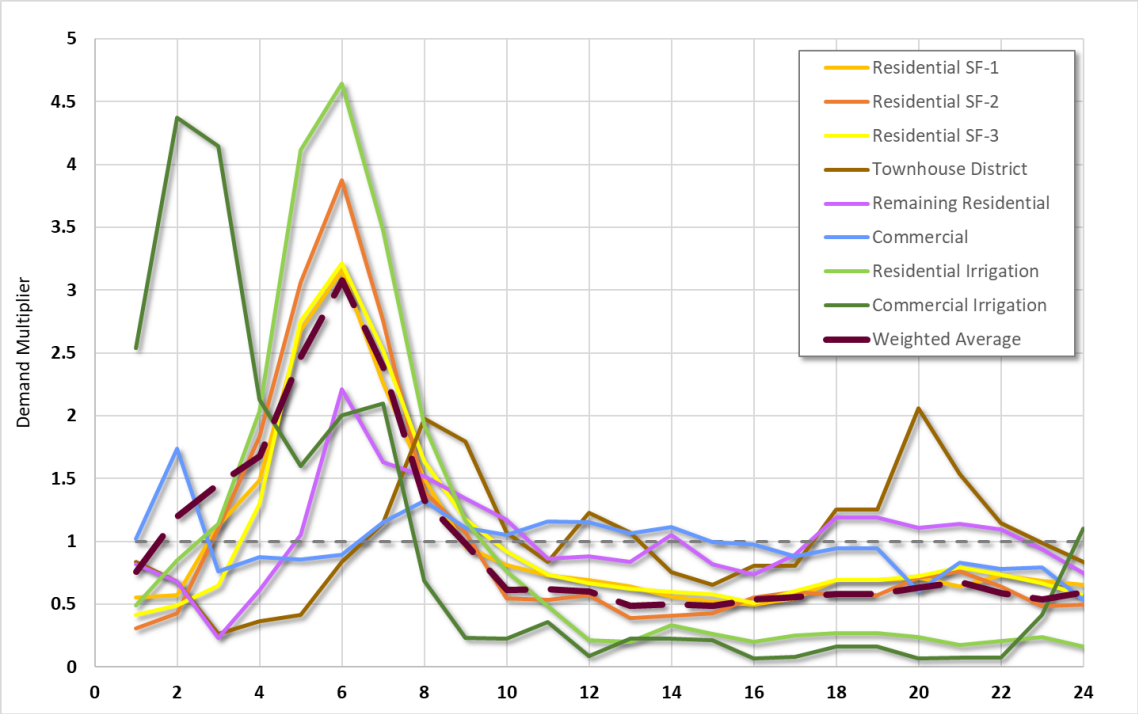
SCALE IN FEET

Created By Freese and Nichols, Inc.
Job No.: WUP20540
Location: H:\W_WW_PLANNING\01_DELIVERABLES\00_FINAL_REPORT\[Figure_5-1]-Subdivisions_and_Zoning.mxd
Updated: Thursday, May 18, 2021 10:55:48 AM
User Name: 03812

1.4.1 Calibration Process

FNI utilized the City's smart water meter data to distribute the demands from the calibration day to the model. The smart meter data was also utilized to develop diurnal patterns specific to the calibration day. Diurnal patterns were developed for each of the eight (8) categories (**Section 1.3**) and are shown on **Figure 1-3**, along with the weighted average of the diurnals.

Figure 1-3: Calibration Day Normalized Diurnal Patterns (August 19, 2020)



Tank Levels and Pump Controls

The City provided SCADA for the pressure testing period that included Bellaire and Wakeforest EST tank levels and pressures at the Milton Water Plant. This SCADA was utilized to set initial EST tank levels and to compare the modeled tank levels throughout the calibration day. GST level controls were added to the model based on the typical operating levels from City staff.

The City also provided pump controls for both water plants based on the Bellaire EST water level. West University designates three different pump control set points based on observed demand conditions:

- Set Point Guidelines (Typical)
- High Usage
- Deep Cycle

These set points have options to lead with the **Wakeforest** pumps or the **Milton** pumps. The 'set point guidelines' with *Milton* pumps leading were utilized during the calibration day and are shown in **Table 1-2.**

Table 1-2: Calibration Day Pump Controls

Facility Name	Pump Number	Control	Pump On	Pump Off
Milton Water Plant	Lead	Bellaire EST Level (feet)	22	28.5
	Lag 1		20	25
	Lag 2		19	24
	Lag 3		17	21
Wakeforest Water Plant	Lead		21	28
	Lag 1		18	22

Calibration Controls and Adjustments

During the EPS calibration, adjustments were made to the model in order to match the known conditions of August 19, 2020. After discussions with City staff, the following adjustments were made to simulate the conditions that occurred over the 24-hour period:

- A valve at Wakeforest EST was added that regulates the water level in the tank. Once the Wakeforest EST tank level drops below a certain point, the valve opens to allow Wakeforest to refill. Whichever pump(s) are on at this time fill the Wakeforest EST.
- The lead and lag pumps at each water plant were selected by analyzing the historical pump runtime data provided by the City. Pump runtime data for the calibration day was unavailable, but historical data was analyzed to identify typical pump usage patterns under similar demand conditions and operational scenarios.
- As part of the calibration process, IDS surveyed the Bellaire EST ground, bottom of the bowl, and overflow elevations. This information was incorporated into the hydraulic model.

1.4.2 Calibration Results

The results of the EPS calibration are summarized in the graphs included in **Appendix H**. The graphs show modeled pressures versus recorded data at pressure recorder locations and modeled tank levels versus recorded levels. Calibration statistics are presented in **Table 1-3**. The percentages shown represent the number of occurrences where the modeled pressures and observed data were within the given ranges of 10 psi, 5 psi, and 3 psi. The results suggest a good correlation between recorded and modeled values and provide a high level of confidence in the accuracy of the model.

Table 1-3: Pressure Calibration Statistical Summary

Pressure Recorder	Within 10 psi	Within 5 psi	Within 3 psi
PR-01	100%	94%	81%
PR-02	100%	94%	85%
PR-03	98%	82%	76%
PR-04	100%	92%	67%
PR-05	100%	97%	93%
PR-06	100%	97%	93%
PR-07	100%	96%	93%
PR-08	100%	99%	95%
Average	**100%**	**94%**	**85%**

APPENDIX G
System Analysis Mapping

FIGURE

CITY OF WEST UNIVERSITY PLACE
WATER SYSTEM ASSESSMENT
MINIMUM PRESSURE ANALYSIS
UNDER PROJECTED MAX DAY DEMAND

LEGEND

- Metered Connection
- Well
- Pump Station
- Water Plant
- Elevated Storage Tank
- Ground Storage Tank
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Road
- Railroad
- City Limit
- Other City Limit

City of West University Place

FREESE AND NICHOLS

MINIMUM PRESSURE

- Less than 35 psi
- 35 - 45 psi
- 45 - 50 psi
- 50 - 55 psi
- Greater than 55 psi

Minimum pressures under projected 6.1 MGD demands with firm capacity pumping. Utilizing high usage set points from the City.

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank

Bellaire

Southside Place

0 900
SCALE IN FEET

Created By Freese and Nichols, Inc.
Job No.: WUP20540
Location: H:\W_WW_PLANNING\01_DELIVERABLES\00_DRAFT_REPORT\01_APPENDIX\Figure_X\Existing_System_Minimum_Pressure_Under_Max_Day_Demands.mxd
Updated: Thursday, May 20, 2021 10:46:12 AM
User Name: 03812

FIGURE

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT

AVAILABLE FIRE FLOW AT 20 PSI UNDER PROJECTED MAXIMUM DAY DEMAND

FIRE FLOW

- Less than 1,000 gpm
- 1,000 - 2,000 gpm
- 2,000 - 3,000 gpm
- 3,000 - 4,000 gpm
- Greater than 4,000 gpm

Available fire flow under projected 6.1 MGD max day demands with firm pumping capacity. Utilizing high usage set points from the City.

LEGEND

- Metered Connection
- Pump Station (PS)
- Elevated Storage Tank
- Ground Storage Tank
- Water Treatment Plant (WTP)
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Road
- Railroad
- City Limit
- Other City Limit

City of West University Place

FREESE AND NICHOLS

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank

0 900
SCALE IN FEET

Created By Freese and Nichols, Inc.
Job No.: WUP20540
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User Name: Thomas.May
Date: May 26, 2021 10:35:44 AM

FIGURE

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT
AVERAGE DAY WATER AGE WITH MILTON WATER PLANT LEADING

LEGEND

- Metered Connection
- Pump Station
- Water Plant
- Elevated Storage Tank
- Ground Storage Tank
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Cast Iron Water Line
- Road
- Railroad
- City Limit
- Other City Limit

City of West University Place

FREESE AND NICHOLS

WATER AGE UNDER AVERAGE DAY DEMANDS

- Less than 1 Day
- 1 - 2 Days
- 2 - 5 Days
- 5 - 10 Days
- Greater than 10 Days

Water age under 2.2 MGD average day demands with three active pumps at Milton and one active pump at Wakeforest. Utilizing 'Set Point Guidelines' from the City as the booster pump set points.

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank

Bellaire

Southside Place

0 900
SCALE IN FEET

Created By Freese and Nichols, Inc.
Job No.: WUP20640
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Updated: Thursday, May 20, 2021 8:37:34 AM
User Name: 03812

FIGURE

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT
AVERAGE DAY WATER AGE WITH WAKEFOREST WATER PLANT LEADING

LEGEND

- Metered Connection
- Pump Station
- Water Plant
- Elevated Storage Tank
- Ground Storage Tank
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Cast Iron Water Line
- Road
- Railroad
- City Limit
- Other City Limit

FREESE AND NICHOLS

City of West University Place

WATER AGE UNDER AVERAGE DAY DEMANDS

- Less than 1 Day
- 1 - 2 Days
- 2 - 5 Days
- 5 - 10 Days
- Greater than 10 Days

Source trace under 2.2 MGD average day demands with two active pumps at Wakeforest and one active pump at Milton. Utilizing 'Deep Cycling Set Point Guidelines' from the City.

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank

Bellaire

Southside Place

WESTERMAN · DRAKE · LAW · NANCY · SERENITY · LAMONT · LAMPTON · ACACIA · MULBERRY · BOULEVARD GREEN · EDLOE · WAKEFOREST · DINCANS · KIRBY · KELVIN · ALBANS · DARTMOUTH · FAIRMONT · SUNSET · LEHIGH · EMORY · JUDSON · SIMMONS · BISSONNET · SPELMAN · BROWNING · ARNOLD · TANGLEY · PLUMB · MARLOWE · COLERIDGE · TENNYSON · WEST POINT · ACADEMY · MILTON · RICE · GEORGETOWN · SEWANEE · MERGER · WESTCHESTER · RUTGERS · WROXTON · NOTTINGHAM · ROBINHOOD · QUENBY · LAFAYETTE · JARRARD · CHARLOTTE · ANNAPOLIS · RORDHAM · LAKE · AMHERST · UNIVERSITY · FENWOOD · PEMBERTON · BARBARA · CAROLINA · PITTSBURG · CENTENARY · ARBUCKLE · TALBOT · CASON · WERLEIN · BELLAIRE · SHAKESPEARE · DRYDEN · SWIFT · ADDISON · WATTS · GOLDSMITH · SOUTHGATE · WORDSWORTH · MC CLENDON · SHERIDAN · TIMES · QUENBY · ROBINHOOD · TANGLEY · DUNSTAN · BOLSOVER · SWARTHMORE · CASE · BYRON · OBERLIN · WESLAYAN · COLLEGE · VILLANOVA · MARQUETTE · SOUTHWESTERN · FAIRHAVEN · RILEY · RUSKIN · STELLA LINK · INGOLD · HARPER · GARNET · FARBER · ELMORA · DARCUS · CARLON · AUDEN · VIRGINIA COURT · BUFFALO SPEEDWAY · DUKE · VANDERBILT · BELMONT · BROMPTON · CARNEGIE · BRADFORD · BRAES · GREENMERCY

Created By Freese and Nichols, Inc.
Job No.: WUP20540
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Updated: Thursday, May 20, 2021 8:17:33 AM
User Name: 03812

0 900
SCALE IN FEET

FIGURE

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT
SOURCE TRACE ANALYSIS
WITH MILTON PLANT LEADING

LEGEND

- Metered Connection
- Pump Station
- Water Plant
- Elevated Storage Tank
- Ground Storage Tank
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Road
- Railroad
- City Limit
- Other City Limit

FREESE AND NICHOLS

City of West University Place

PERCENT WATER FROM MILTON WATER PLANT

- Under 20%
- 20 - 40%
- 40 - 60%
- 60 - 80%
- 80 - 100%

Source trace under 2.2 MGD day demands with three active pumps at Milton and one active pump at Wakeforest. Utilizing 'Set Point Guidelines' from the City as the booster pump set points.

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank

Bellaire

Southside Place

0 900
SCALE IN FEET

Created By:Freese and Nichols, Inc.
Job No.: WUP20540
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Date Saved: Wednesday, May 19, 2021 3:48:18 PM
User Name: 03812

FIGURE

CITY OF WEST UNIVERSITY PLACE

WATER SYSTEM ASSESSMENT
SOURCE TRACE ANALYSIS
WITH WAKEFOREST PLANT LEADING

LEGEND

- Metered Connection
- Pump Station
- Water Plant
- Elevated Storage Tank
- Ground Storage Tank
- 8" and Smaller Water Line
- 10" and Larger Water Line
- Road
- Railroad
- City Limit
- Other City Limit

City of West University Place

FREESE AND NICHOLS

PERCENT WATER FROM MILTON WATER PLANT

- Under 20%
- 20 - 40%
- 40 - 60%
- 60 - 80%
- 80 - 100%

Source trace under 2.2 MGD average day demands with two active pumps at Wakeforest and one active pump at Milton. Utilizing 'Deep Cycling Set Point Guidelines' from the City.

Wakeforest Water Plant
Metered Surface Water Connection (Houston)

Bissonnet Metered Surface Water Connection (Houston)
Transmitted directly to Milton Water Plant

Milton Water Plant

Bellaire Elevated Storage Tank
(1) Elevated Storage Tank - 0.25 MG

Bellaire

Southside Place

0 900
SCALE IN FEET

Created By Freese and Nichols, Inc.
Job No.: WUP20540
Location: H:\WU_WW_PLANNING\01_DELIVERABLES\04_Existing_System_Analysis\Figure_X\Existing_System_Source_Trace_Wakeforest_Plant_Leading.mxd
Last Edited: Thursday, May 20, 2021 8:02:07 AM
User Name: 03812

APPENDIX H
Water Model Calibration Results

City of West University Place

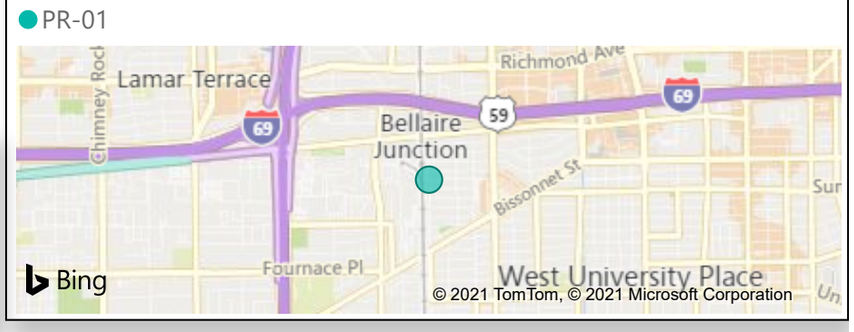
Water System Assessment

Water Model Pressure Calibration

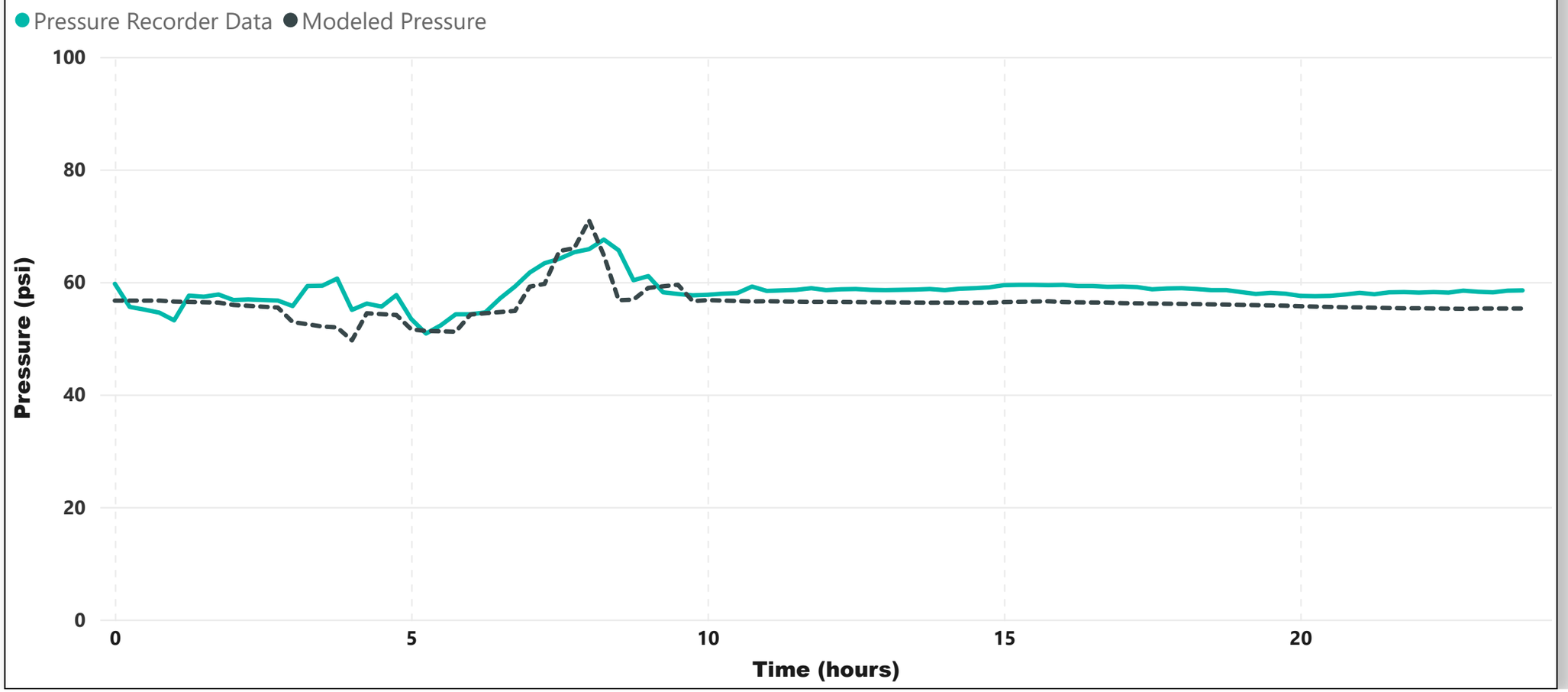
Pressure Recorder ID

PR-01 | PR-02 | PR-03 | PR-04 | PR-05 | PR-06 | PR-07 | PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

93.75%

within 3 psi

81.25%

City of West University Place

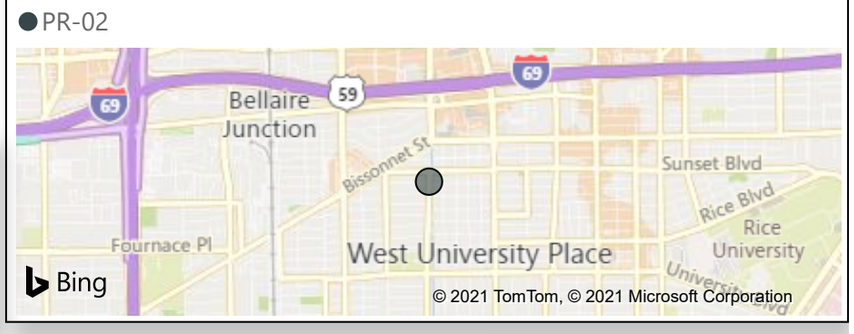
Water System Assessment

Water Model Pressure Calibration

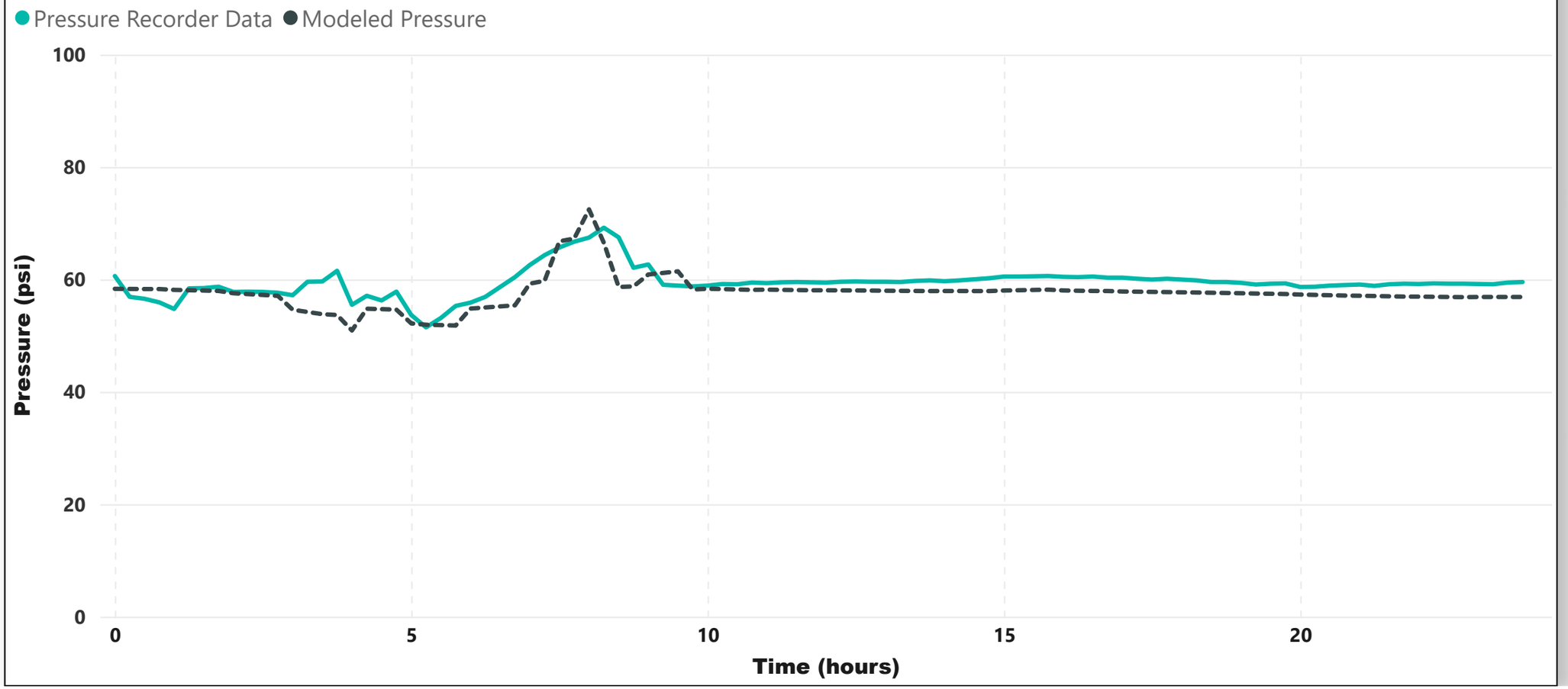
Pressure Recorder ID

PR-01	PR-02	PR-03	PR-04	PR-05	PR-06	PR-07	PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

93.75%

within 3 psi

85.42%

City of West University Place

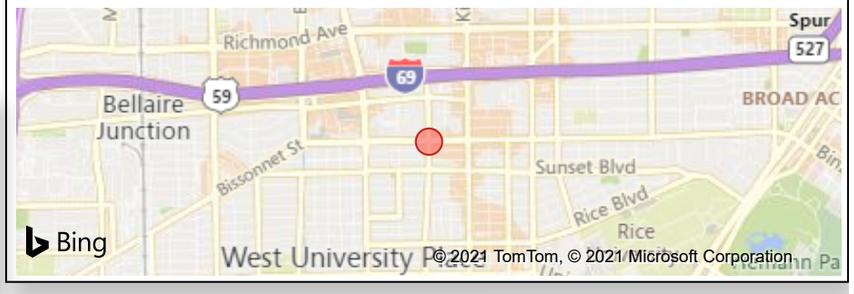
Water System Assessment

Water Model Pressure Calibration

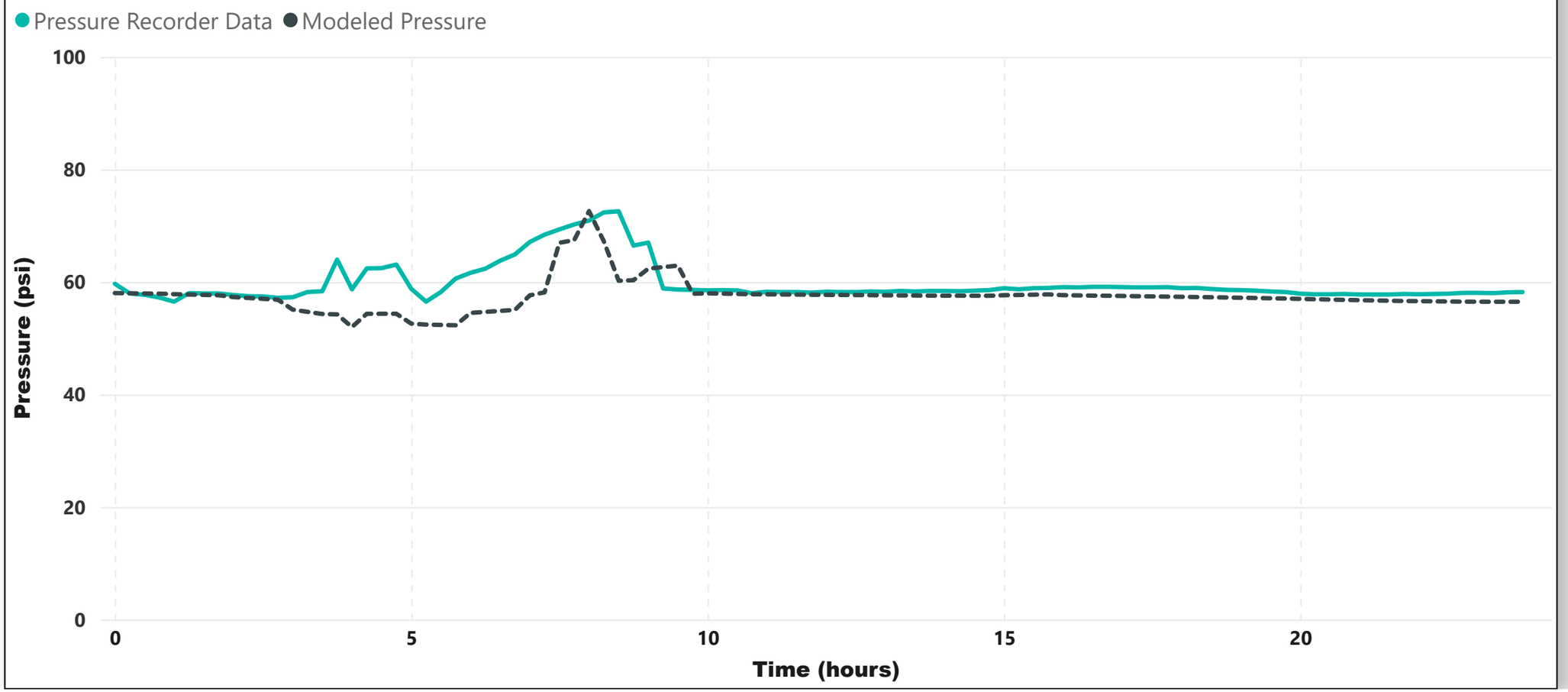
Pressure Recorder ID

PR-01	PR-02	PR-03	PR-04	PR-05	PR-06	PR-07	PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

97.92%

within 5 psi

82.29%

within 3 psi

76.04%

City of West University Place

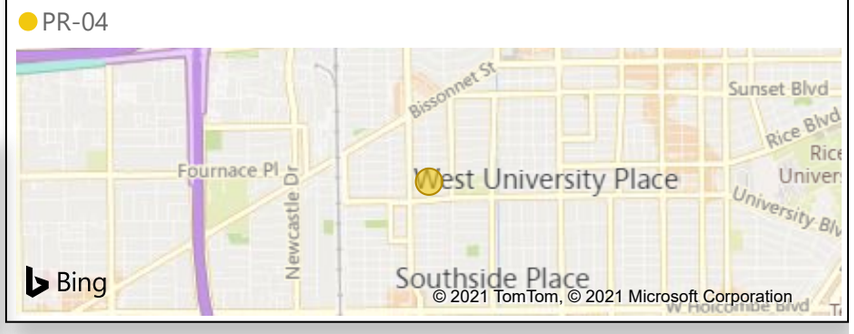
Water System Assessment

Water Model Pressure Calibration

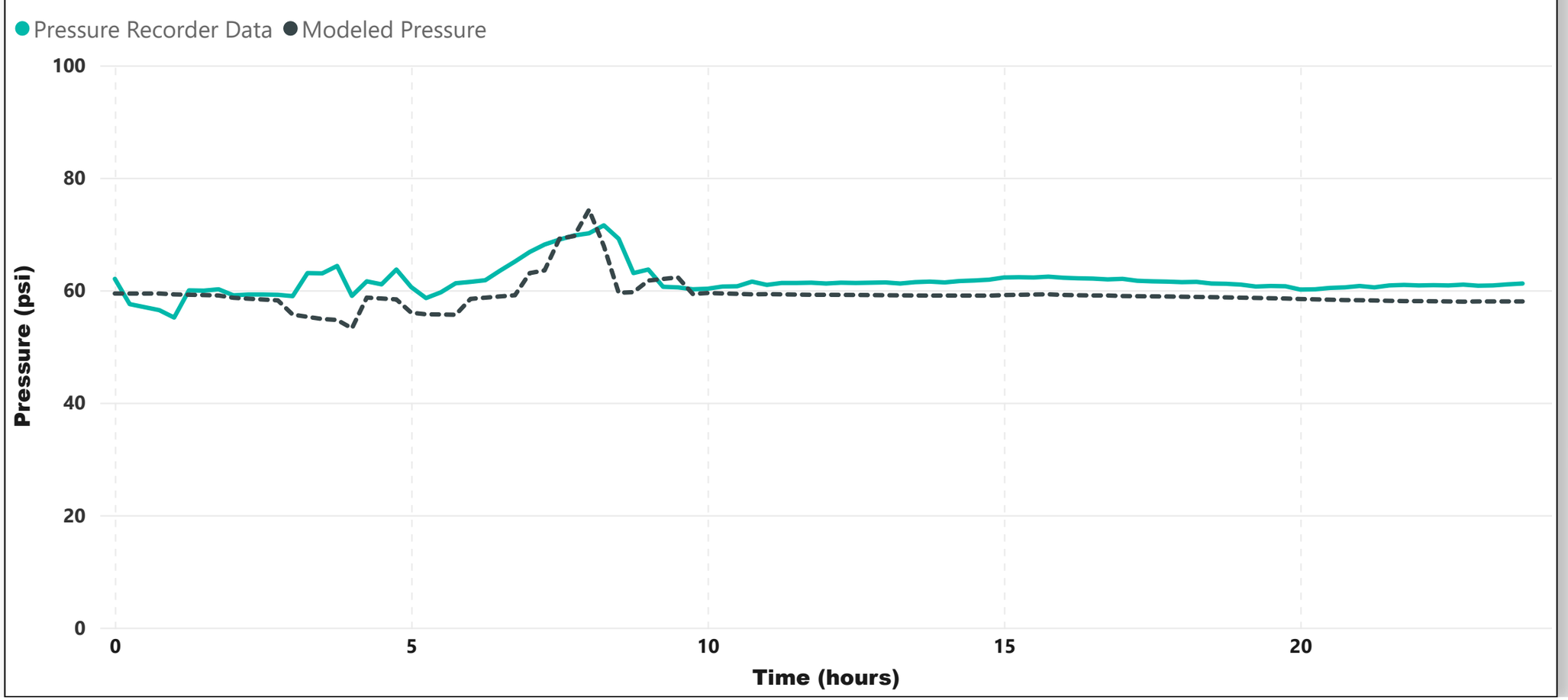
Pressure Recorder ID

PR-01	PR-02	PR-03	PR-04	PR-05	PR-06	PR-07	PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

91.67%

within 3 psi

67.71%

City of West University Place

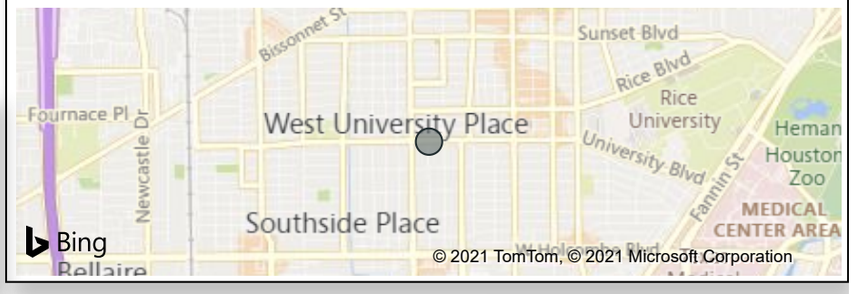
Water System Assessment

Water Model Pressure Calibration

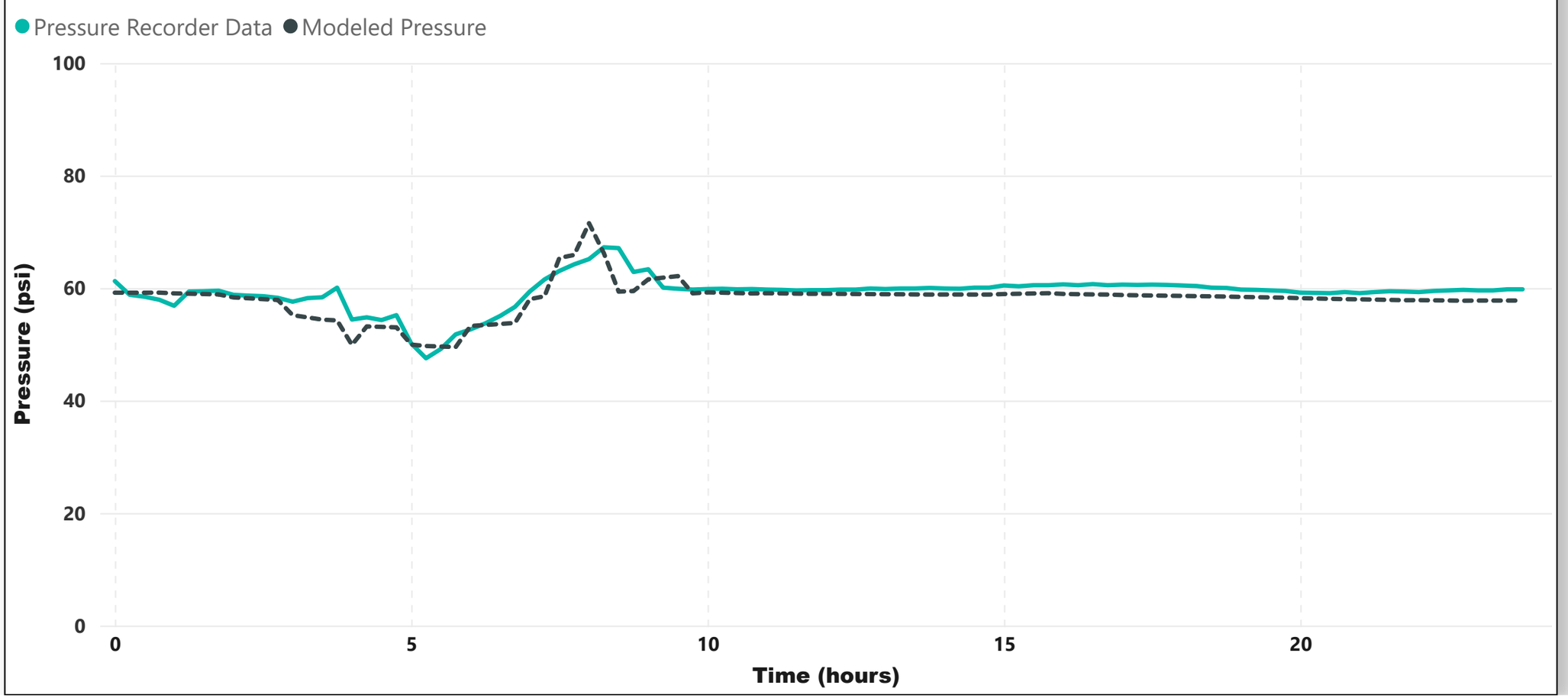
Pressure Recorder ID

PR-01	PR-02	PR-03	PR-04	PR-05	PR-06	PR-07	PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

96.88%

within 3 psi

92.71%

City of West University Place

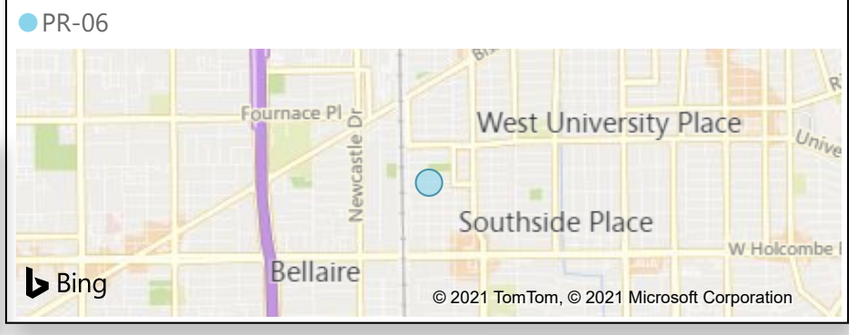
Water System Assessment

Water Model Pressure Calibration

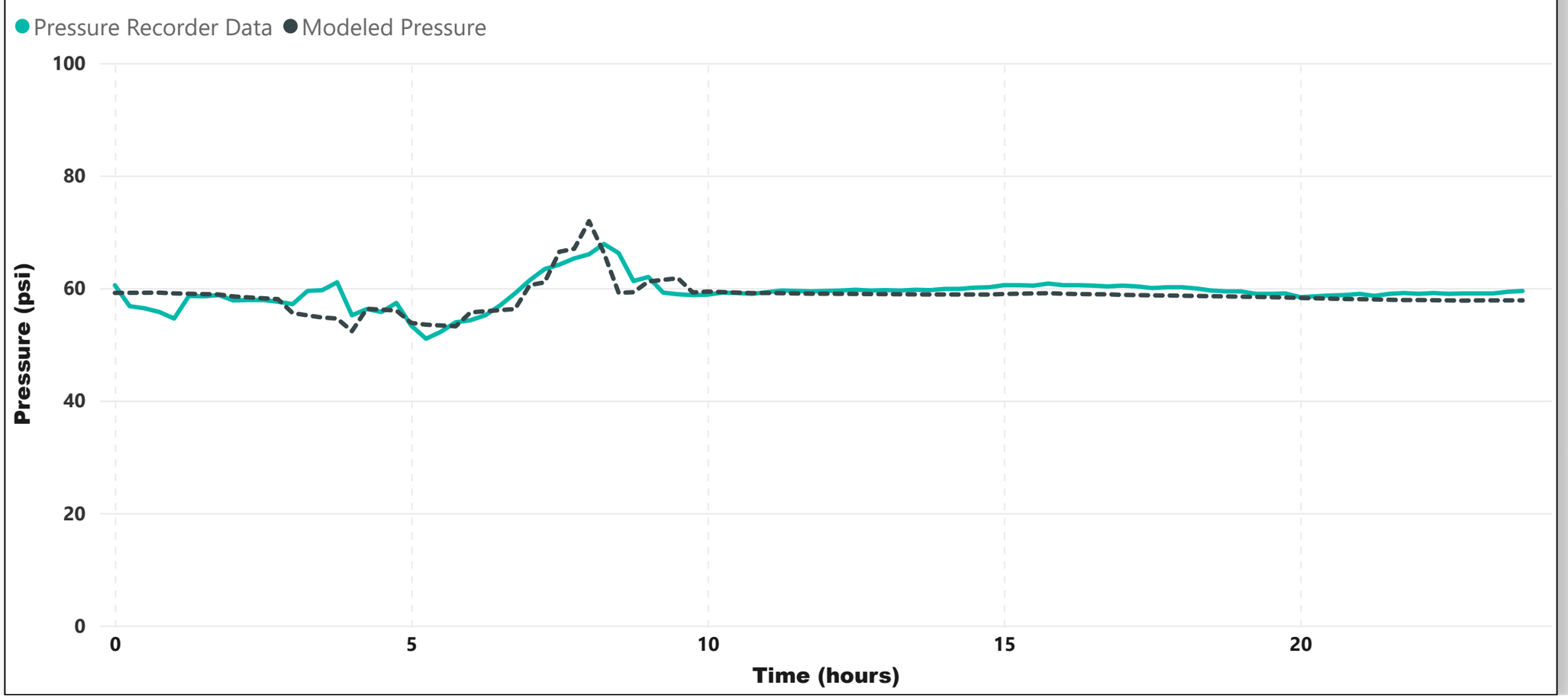
Pressure Recorder ID

PR-01 | PR-02 | PR-03 | PR-04 | PR-05 | **PR-06** | PR-07 | PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

96.88%

within 3 psi

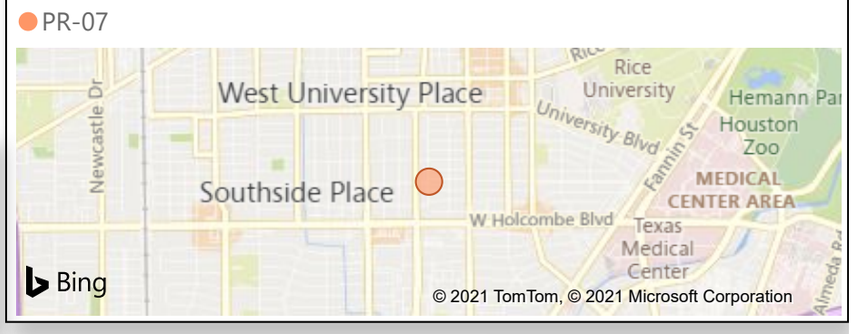
92.71%

City of West University Place
Water System Assessment
Water Model Pressure Calibration

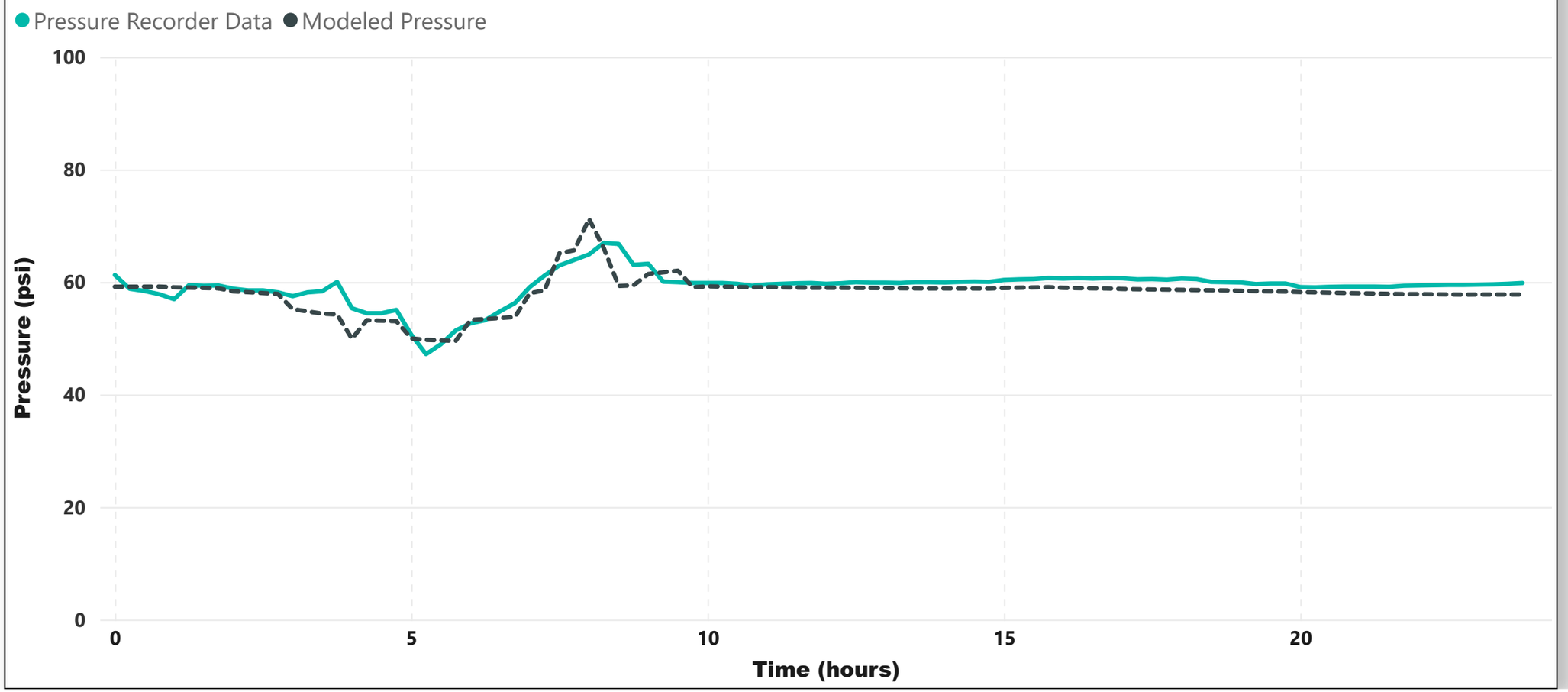
Pressure Recorder ID

PR-01 | PR-02 | PR-03 | PR-04 | PR-05 | PR-06 | **PR-07** | PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

within 5 psi

95.83%

within 3 psi

92.71%

City of West University Place

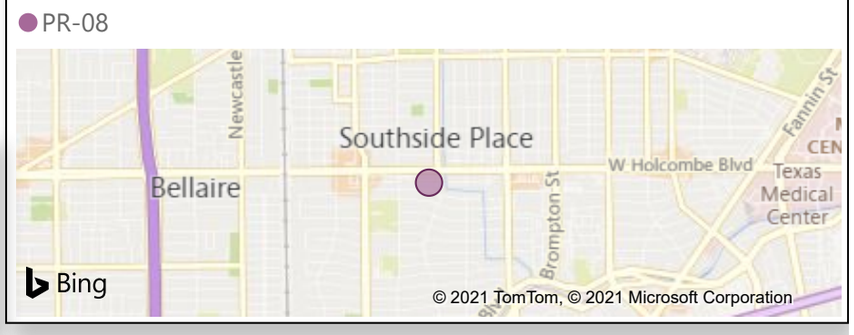
Water System Assessment

Water Model Pressure Calibration

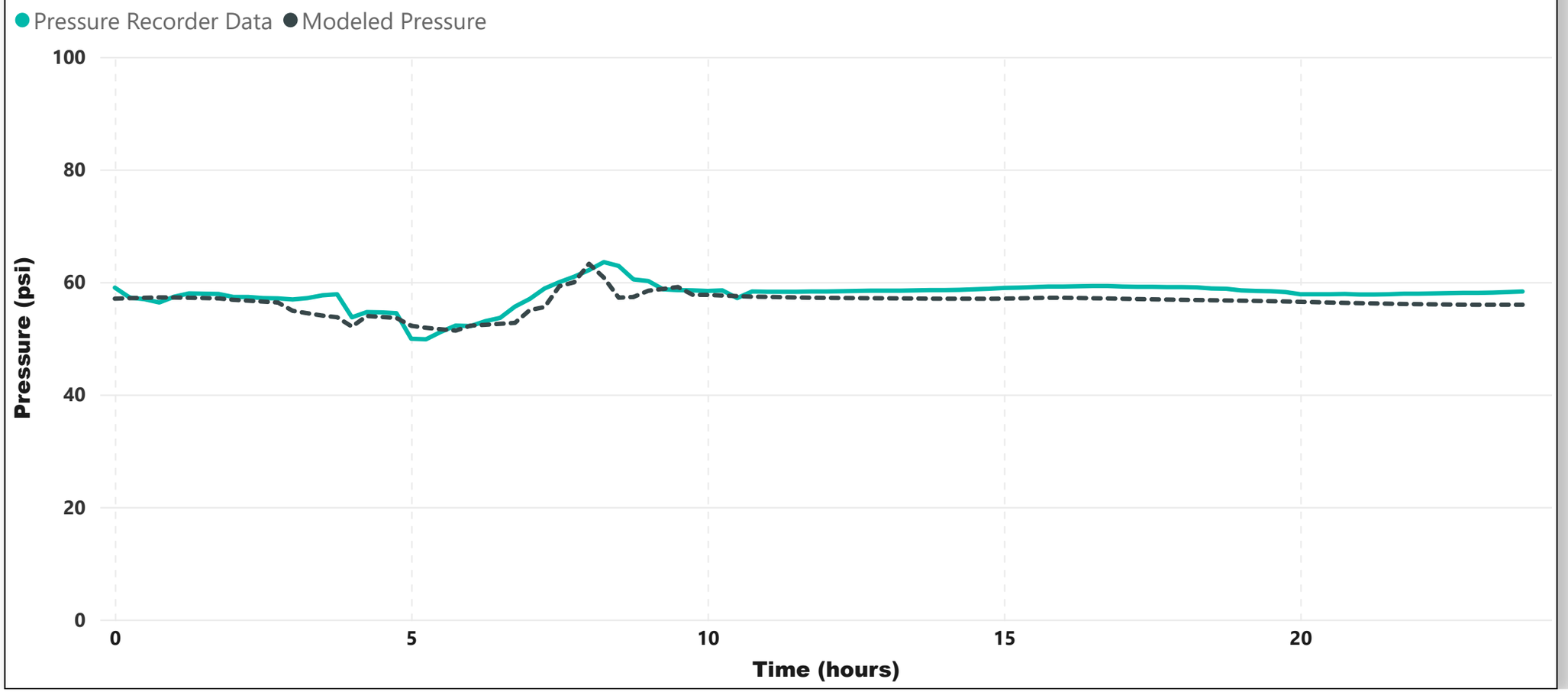
Pressure Recorder ID

PR-01	PR-02	PR-03	PR-04	PR-05	PR-06	PR-07	PR-08

Pressure Recorder Location



Model Calibration Results



within 10 psi

100.00%

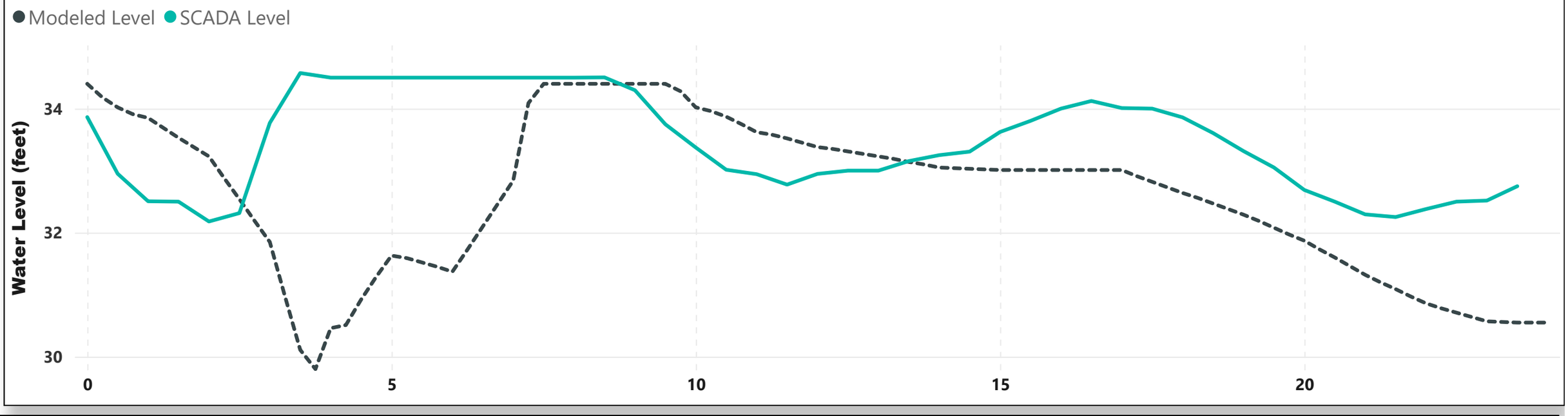
within 5 psi

98.96%

within 3 psi

94.79%

Wakeforest EST Levels



Bellaire EST Levels