Program Thesis and Design for a Diesel Pumping Efficiency Program

Developed by:

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I. The Basic Thesis

IMPORTANT *– as of 2/28/06 the numbers in this document have changed from our original proposals to the US EPA and the Valley CAN group that are now funding our pilot project-level DPEP. These changes are due to actual field measurements from 52 completed pump efficiency tests and 2 pumping plant retrofits, as well as in depth interviews with pump operators.*

The diesel-powered pumping plant should be viewed as a system of at least FOUR components:

1. The power source
2. The transmission system (gear drive, line shaft, v-belts, close-couple)
3. The pump itself
4. The management of the system

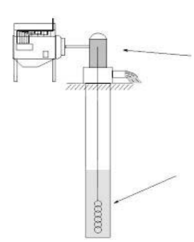
Emissions are increased to the extent that there are inefficiencies in any one of these components. As examples:

1. Runtimes are increased due to an inefficient pump or management.
2. The engine is speeded up to compensate for a worn pump and is run off of its design operating condition (i.e. increasing fuel consumption per acre-foot of water and possibly increasing emissions per unit fuel consumed).
3. An outdated engine design, or an engine out of tune, results in increased emissions.

Note the first two examples where the pump and/or management are the cause of excessive emissions. The figure and example numbers at right are an example of an inefficient pumping plant, but with an efficient power source. We can make conservative estimates of engine and transmission system efficiencies- in this case 31.9% and 95% respectively. Thus, a pump efficiency test will allow an estimate of the pump bowl efficiency. Then, since we also know potential pump efficiencies we can make informed estimates as to fuel-use and emission reductions resulting from an efficient pump in place.

In the example at right, the overall pumping plant is operating at 13.8% efficiency. That is, only 13.8% of the horsepower input to the plant in the form of diesel fuel is converted to water horsepower. This is even as the engine and transmission system are operating fairly efficiently.

34.6% engine x 95.0% cooling x 99.0% alternator x 98.0% muffler = 31.9% Power Plant efficiency



Gearhead/Shaft = 95.0% efficiency

Pump = 45.5% efficiency

31.9% x 95% x 45.5% = **13.8% Current Overall Pumping Plant Efficiency (OPE)**

Since we know potential bowl efficiencies (which may range from 75-85%) we know that this plant could potentially be operating at 24-26% efficiency (e.g. at 80% bowl efficiency, OPE = .32 x .95 x .80 = .24), an improvement of 74 – 88%. Using engineering relationships and current accepted values for engine performance we can then make estimates of reductions in emissions and fuel use.

The proposed Diesel Pumping Efficiency Program (DPEP) is intended to address inefficiencies in the pump itself and management. As such it is intended to augment existing programs such as Carl Moyer that currently only provide for engine replacements. **We estimate that on average, each pump retrofit, where a pump retrofit is warranted as indicated by a pump efficiency test, will result in 3.57 tons of reduced NOx emissions, .20 tons of reduced PM10 emissions, and savings of 26,817 gallons of diesel fuel. If using the current experience of the Agricultural Pumping Efficiency Program for pumps of 50-150 horsepower (average cost of the incentive rebate to the pump owner) the proposed DPEP would deliver NOx emissions reduction at the rate of $955/ton.** An estimate by Cal EPA Air Resources Control Board for the year 2000 indicated a total of 7,253 diesel pumping units, with 3,473 stationary units of which about half (1,599 engines) were 175 hp. With effective marketing and public awareness, it is projected that as many as 100 applications per year would be submitted for incentive rebates.

The details of our analysis follow.

II. Detail of Emissions and Fuel Use Reductions Estimates

II.1 Experience from Electric-Powered Pumping Plant Retrofits as a Starting Point

The Center for Irrigation Technology (CIT) currently manages the Agricultural Pumping Efficiency Program (APEP) on behalf of the California Public Utilities Commission. APEP provides for subsidized pump efficiency tests and incentive rebates for pump retrofit/retrofit. It has provided over 7,300 tests and 460 pump retrofits since June, 2002. (Note that APEP only operates in the service areas of the four major investor-owned utilities in California and only with electric or natural gas-powered pumping plants.)

An analysis of the APEP pump retrofit database for electric-powered pump was performed for 41 large pumps (75 to 300 hp) that had efficiency tests before and after the retrofit. The electric-powered pumps are used as a model for diesel irrigation pumping conditions. Table 1 contains a summary of this analysis.

The column headings in Table 1 are explained as follows:

- Column 1, Condition – Average statistics from pump tests before or after the retrofit
- Column 2, OPE – Overall pumping plant efficiency measured in the field and averaged
- Column 3, Post-Motor OPE – Since we know the approximate efficiency of large horsepower electric motors, we can estimate the efficiency of the combined transmission system and pump. In Table 1 we are using a conservative 90% as motor efficiency. Thus:

  Post-Motor OPE = Col 2 / .9 [1]

- Column 4, GPM – Water flow from the pump in gallons per minute measured in the field and averaged.
- Column 5, Total Dynamic Head – Total pressure developed by the pumping plant in feet of water head and averaged.
- Column 6, Input HP – Total power input to the pumping plant calculated from columns 2 (as a decimal), 4, and 5 as:

Input HP = Col 4 x Col 5 / (3960 * Col 2) [2]

- Column 7, kWh/Acre-Foot – Number of kilowatt-hours required to pump an acre-foot of water through the system calculated from columns 2 (as a decimal) and 5 as:

kWh/Acre-foot = 1.0241 * Col 5 / Col 2 [3]

- Column 8, Annual Acre-Feet Pumped – Total acre-feet of water pumped per year. 400 acre-feet/year is an average number for a water well supplying about 160 acres in the Central Valley of California. (The average for these pumps, where self-reported, was 403 acre-feet.)

- Column 9, Annual Hours Operation – Total annual hours of operation needed for the Acre-Feet pumped calculated from columns 8 and 4 as:

Hours = 5431.7 * Col 8 / Col 4 [4]

- Column 10, Annual kWh – Total kilowatt-hours required to pump the Acre-Feet pumped annually calculated from columns 7 and 8 as:

Annual kWh = Col 7 * Col 8 [5]

Table 1 – Electric-powered pump retrofit statistics for 41 pumps ranging from 75 to 300 horsepower

1	2	3	4	5	6	7	8	9	10
Condition	**OPE (%)**	**Post-Motor OPE (%)**	**GPM**	**Total Dynamic Head (ft)**	**Input Horsepower**	**kWh/ Acre-Foot**	**Annual Acre-Feet Pumped**	**Annual Hours Operation**	**Annual kWh**
Before Retrofit	38	42	893	274	163	738	400	2,433	295,372
After Retrofit	65	72	1,372	316	168	498	400	1,584	199,148
Estimated or Measured	Meas	Est	Meas	Meas	Est	Est	Est	Est	Est

In Table 1 note that although the Input HP increased after the retrofit (as it often will since the flow will usually increase as the result of a retrofit), the kWh/Acre-Foot decreased by 33%, the Annual Hours of Operation decreased 35%, and the kilowatt-hours required per year decreased 33%.

The useful life of a pump under good conditions (a correctly installed and maintained pumping plant pumping relatively clean water) is estimated at about 20,000 hours. At the rate of utilization indicated by these 41 pumps, the pump and other rotating components would be replaced after about 9 years of operation. A common practice for low-use electric-powered pumps is to wait until the pump totally deteriorates (either mechanical breakage, or water flow so low in output that it is not worth running). High-use pumps, such as those seen in Table 1, are retrofitted (or rebuilt) when an economic threshold is reached that allows payback of retrofit costs from energy savings within a period of 2 to 3 years.

II.2 The Role of the Incentive Rebate in Reducing the Time Between Pump Retrofits

The purpose of the “incentive” rebate is to encourage the owner to shorten the retrofit cycle and thus avoid excessive consumption of energy. The rebate reduces the cost of the project and this, in conjunction with expected fuel savings, shortens the payback period. Estimates for the savings in energy use and costs for a normal retrofit cycle versus an accelerated retrofit cycle are presented in Table 2.

Table 2 estimates that the normal retrofit cycle is nine years. However, since our retrofit experience noted in Table 1 above is for incented retrofits we are inserting the 42% Post-Motor OPE at year 6, assuming that we are reducing the retrofit cycle by approximately 3 years. Doing this, and slowing the rate of deterioration somewhat past the 42% mark results in approximately 20,000 hours of operation during a normal retrofit cycle. The 6-year Accelerated Retrofit cycle results in 11,760 hours of operation per retrofit cycle and 16,877 hours when compared over nine years to a 9-year Normal cycle.

In Table 2 below:

- Columns 2, 3, and 5, Post-Engine OPE, Pump Flow, and Total Dynamic Head - the deterioration in pump performance in Year 1 to Year 6 is estimated as a constant process. The rate of deterioration is slowed after Year 6 as a conservative estimate of field performance.

- Column 4, Annual Hours of Operation - calculated from column 3 and 400 acre-feet pumped annually as:

  Hours of Operation = 400 AF/Year x 325,900 gallons/AF / (60 min/hour x Col 3) [6]

- Column 6, kilowatt-hours required to pump an acre-foot of water - calculated from columns 2 (as a decimal) and 5 as:

  kWh/Acre-Foot = 1.0241 x Col 5 / Col 2 [7]

- Column 7, Annual kWh Use - calculated from the 400 acre-feet pumped per year and column 6 as:

  kWh/Year = 400 x Col 6 [8]

- Column 8, kWh Use Savings - calculated using the totally deteriorated annual use of Year 9 minus column 7 for that year. Thus, for Year 1:

  Col 8 = 325,229 – 179,786 (Col 7 for year 1)

  And for Year 2:

  Col 8 = 325,229 – 190,917 (Col 7 for year 2)

- Column 9, Annual kWh Cost - calculated from column 7 and an average $.1174/kWh as:

  Col 9 = Col 7 x .1174 [9]

- Column 10, kWh Cost Savings, - calculated using the totally deteriorated annual cost of Year 9 minus column 9 for that year. Thus, for Year 1:

  Col 10 = 38,182 – 21,107 (Col 9 for year 1)

  And for Year 2:

  Col 10 = 38,182 – 22,414 (Col 9 for year 2)

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Table 2 – Energy and energy cost savings for a pump as described by Table 1 with a 9-year Normal Retrofit cycle versus a 6-year Accelerated Retrofit cycle (400 acre-feet pumped annually)

1	2	3	4	5	6	7	8	9	10
Year	Post-Motor OPE (%)	Flow (gpm)	Annual Operating Hours	Total Dynamic Head	kWh/AF	Annual kWh Usage	kWh Use Savings	Annual kWh Cost	kWh Cost Savings
1	72	1372	1,584	316	449	179,786	145,443	$21,107	$17,075
2	66	1276	1,702	308	477	190,917	134,312	$22,414	$15,768
3	60	1180	1,841	299	511	204,274	120,956	$23,982	$14,200
4	54	1085	2,003	291	551	220,599	104,631	$25,898	$12,284
5	48	989	2,197	282	603	241,005	84,224	$28,294	$9,888
6	42	893	2,433	274	668	267,241	57,988	$31,374	$6,808
7	38	829	2,621	269	725	289,982	35,247	$34,044	$4,138
8	35	781	2,782	265	775	310,156	15,073	$36,412	$1,770
9	33	749	2,901	262	813	325,229	0	$38,182	$0
TOTAL for Years 1 - 9 (Normal Retrofit)			20,064			2,229,190		$261,707	
TOTAL for Years 1 - 6 (Accelerated Retrofit)			11,760			1,303,822		$153,069	
TOTAL for Accelerated Retrofit over 9 years			16,887			1,878,800		$220,571	
Savings of Accelerated Retrofit Cycle vs Normal Cycle over 9 years			**3,177**			**350,390**		**$41,136**	

1. Average cost per kilowatt-hour for AG5B rate schedule in PG&E is $0.1174 (2001)

The last four rows of Table 2 are explained as follows:

- TOTAL for Years 1 - 9 (Normal Retrofit) – these are the totals for a 9-year Normal Retrofit cycle.

- TOTAL for Years 1 - 6 (Accelerated Retrofit) – these are the totals for a pump that is retrofitted at the end of 6 years operation for those 6 years.

- TOTAL for Accelerated Retrofit over 9 years – these are the totals for a pump retrofitted on the accelerated 6-year cycle but over 9 years so as to compare appropriately to the Normal Retrofit cycle. This is equal to the totals for 6 years plus the total for the first 3 years of a cycle. For example, 16,877 Annual Operating Hours = 11,760 hours + (1,584 + 1,702 + 1,841); the 11,760 hours representing a full 6-year cycle and the next three numbers representing the first 3 years of a cycle.

- **Savings of Accelerated Retrofit Cycle vs Normal Cycle over 9 years – this is the difference between the Total for Years 1 – 9 (a Normal Retrofit cycle) and the Total for the Accelerated Retrofit Cycle over 9 years. For example, the savings in Annual Operating Hours = 20,064 – 16,877 = 3,177.**

Thus, Table 2 indicates that retrofitting the pump described every 6 years instead of every 9 years saves 3,177 operating hours, 350,390 kilowatt-hours, and $41,136 in energy costs. It is noted that the bulk of the savings occurs in the first three years after a retrofit.

II.3 Accelerated Retrofit Cycles Applied to Diesel-Powered Pumping Plants

While many diesel irrigation pumps are similar in horsepower requirements, it is unknown how closely diesel irrigation pumps follow the model presented above. However, common sense and observations from the field suggest that the model is overly conservative. Diesel-powered pumps are unique in the sense that owners can regain their lost capacity by speeding up the pump. When this occurs, horsepower, fuel usage, and emission increases are cubed compared to the RPM increase (due to what are known as the Affinity Laws). Therefore, it is likely that the comparison between these electric retrofits and a typical diesel-powered pumping plant currently underestimates the benefits that can be achieved from an incentive retrofit program for diesels because of two reasons: 1) testing services are not widely available for diesel-powered pumps and thus, owners are generally unsuspecting of pump problems and inefficiencies, 2) revving the diesel motor can allow an owner to "get by" (i.e. maintain the required water flow) for more years, whereas electric-powered pumps (with a set speed) that have lost their capacity restrict the number of acres that can be farmed and force a retrofit.

IMPORTANT! *One of the objectives of the proposed DPEP is too reduce the effect of the two factors just noted. We intend that the educational program, coupled with pump test subsidies, will encourage pump owners to begin testing their plants on a regular basis. Thus, retrofits will probably occur on a more frequent basis and this will reduce the need for over-revving engines. Over time, the need for a program like DPEP should decrease.*

In the case of air quality, a subsidized pump efficiency test and an incentive rebate towards a retrofit would encourage a farmer to make a retrofit of a worn pump sooner- basing his decision on fuel and operational cost savings. Thus, as with the electric-powered pump depicted in Table 2, the high efficiency cycle is started earlier than the 20,000 hour useful life cycle period. An added benefit to the farmer would be to reduce the total hours of engine time to deliver the same amount of water. This would tend to keep the engine burning more efficiently, as engine retrofits would be less frequent. Fewer overhauls would be required, and the engine would last more years, a benefit to both the farmer and the environment.

Based on the model in Tables 1 and 2, a projection for diesel-powered pumping plants is shown below as Table 3. In Table 3:

- Columns 2, 3, 4, and 5 - the deterioration in pump performance in Year 1 to Year 6 is estimated as a constant process. The rate of deterioration is slowed after Year 6 as a conservative estimate of field performance. These numbers are identical to those in Table 2.

- Column 6, Brake Horsepower Input - calculated from columns 2 (as a decimal), 3, and 5 as:

  Brake Horsepower = (Col 3 x Col 5) / (3960 x Col 2) [10]

- Column 7, Brake Horsepower Hours/Year - calculated from columns 4 and 6 as:

  Brake Horsepower-Hours/year = Col 4 x Col 6 [11]

- Column 8, Brake Horsepower Hours Savings - the difference between that year's BHP-hours and the maximum BHP-hours used seen in Year 9.

- Column 9, NOx Emissions - calculated from column 7 and CARB specification for Tier 1 diesel engines of 6.9 grams/bhp-hour as:

Col 9 = Col 7 x 6.9 gms/bhp-hr / 907,200 gms/ton [12]

- Column 10, NOx Savings - the difference between that year's NOx emissions and the maximum NOx emissions seen in Year 9.

- Column 11, PM10 Emissions - calculated from column 7 and CARB specification for Tier 1 diesel engines of .38 grams/bhp-hour as:

Col 11 = Col 7 x .38 gms/bhp-hr / 907,200 gms/ton [13]

- Column 12, PM10 Savings - the difference between that year's PM10 emissions and the maximum PM10 emissions seen in Year 9.

- Column 13, Diesel Fuel Use - calculated from column 7 and a specific fuel consumption rate of 17.5 bhp-hours/gallon as:

Col 13 = Col 7 / 17.5 [14]

- Column 14, Diesel Usage Savings - the difference between that year's fuel use and the maximum fuel use seen in Year 9.

- Column 15, Diesel Fuel Cost - calculated from column 13 and an average cost of $2.00/gallon of fuel as:

Col 15 = 2 x Col 13 [15]

- Column 16, Diesel Fuel Cost Savings - the difference between that year's fuel cost and the maximum fuel cost seen in Year 9.

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Table 3 – Emissions, energy and energy cost savings for a diesel-powered pump as described by Table 1 with a 9 year Normal Retrofit cycle versus a 6.5 Accelerated Retrofit cycle (400 acre-feet pumped annually)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Year	Pumping Plant Performance					Energy Use (bhp-hours)		Annual Emissions (tons)				Annual Diesel Fuel			
								NOx		PM10					
	Post-Engine OPE (%)	Flow (gpm)	Annual Hours	Total Dynamic Head (ft)	Post-Engine Brake HP	Usage	Savings	Output	Reductions	Output	Reductions	Usage[3] (gal)	Usage Savings (gal)	Cost @ $2.00/gal	Cost Savings
1	72	1372	1,584	316	152	240,798	194,800	1.83	1.48	0.10	0.08	13,760	11,131	$27,520	$22,263
2	66	1276	1,702	308	150	255,706	179,892	1.94	1.37	0.11	0.08	14,612	10,280	$29,224	$20,559
3	60	1180	1,841	299	149	273,595	162,002	2.08	1.23	0.11	0.07	15,634	9,257	$31,268	$18,515
4	54	1085	2,003	291	147	295,460	140,137	2.25	1.07	0.12	0.06	16,883	8,008	$33,767	$16,016
5	48	989	2,197	282	147	322,791	112,806	2.46	0.86	0.14	0.05	18,445	6,446	$36,890	$12,892
6	42	893	2,433	274	147	357,931	77,666	2.72	0.59	0.15	0.03	20,453	4,438	$40,906	$8,876
7	38	829	2,621	269	148	388,389	47,209	2.95	0.36	0.16	0.02	22,194	2,698	$44,387	$5,395
8	35	781	2,782	265	149	415,409	20,189	3.16	0.15	0.17	0.01	23,738	1,154	$47,475	$2,307
9	33	749	2,901	262	150	435,597	0	3.31	0.00	0.18	0.00	24,891	0	$49,783	$0
TOTAL for Years 1 - 9 (Normal Retrofit)			20,064					22.71		1.25		170,610		$341,220	
TOTAL for Years 1 - 6.5 (Accelerated Retrofit)			11,760					13.28		0.73		99,787		$199,575	
TOTAL for Accelerated Retrofit over 9 years			16,887					19.14		1.05		143,793		$287,586	
Savings of Accelerated Retrofit vs Normal Cycle over 9 years			**3,177**					**3.57**		**0.20**		**26,817**		**$53,634**	

1. NOx reductions for Tier 1 diesel engines at 6.9 gms/bhp-hr, 1 ton = 907,200 gms
2. PM10 reductions for Tier 1 diesel engines at 0.38 gms/bhp-hr, 1 ton = 907,200 gms -
3. Diesel fuel usage at 17.5 bhp-hrs/gal

The last four rows of Table 3 are explained as follows:

- TOTAL for Years 1 - 9 (Normal Retrofit) – these are the totals for a 9-year Normal Retrofit cycle.
- TOTAL for Years 1 - 6 (Accelerated Retrofit) – these are the totals for a pump that is retrofitted at the 6 year mark over those 6 years.
- TOTAL for Accelerated Retrofit over 9 years – these are the totals for a pump retrofitted on the accelerated 6-year cycle but over 9 years so as to compare appropriately to the Normal Retrofit cycle. This is equal to the totals for 6 years plus the total for the first 3 years of a cycle. For example, 16,887 Annual Operating Hours = 11,760 hours + (1,584 + 1,702 + 1,841); the 11,760 hours representing a full 6-year cycle and the next three numbers representing the first 3 years of a cycle.
- **Savings of Accelerated Retrofit vs Normal Cycle over 9 years – this is the difference between the Total for Years 1 – 9 (a Normal Retrofit cycle) and the Total for the Accelerated Retrofit Cycle over 9 years. For example, the savings in Annual Operating Hours = 20,064 – 16,877 = 3,177.**

Thus, Table 3 indicates that retrofitting the pump described every 6 years instead of every 9 years saves 3,177 operating hours, 3.57 tons of NOx emissions, .20 tons of PM10 emissions, and 26,817 gallons of diesel fuel. It is noted that the bulk of the savings occurs in the first three years after a retrofit.

III. Proposed Program Components

III.1 Air Quality and Diesel-Powered Pumping Plants as a Non-Point Source Problem

We look at air quality, as well as energy and water conservation, in the form of a non-point source problem (NPS). That is, it has the characteristics of non-point source problems and thus, the program designed to address air quality should use the model of non-point source programs as a starting point.

NPS have several defining characteristics that add considerable political, economic, and engineering complexity to solving these types of problems:

- The source of the problem is diffuse. That is, there are multiple sources of the problem.
- Each individual source may be operating "legally". That is, the activity is legal and is also being conducted to prevailing community and business standards. Importantly, the activity may be (or may have been) encouraged by society (e.g. use of fertilizer to increase crop yields).
- Few, if any, of the individual sources on their own are causing a problem as a legal or practical matter.
- The problem is caused by the cumulative effect of the diffuse sources.
- Because NPS are generally slow to appear, the activities causing the problem are many times "entrenched". That is, they are the result of long-term investments both in money to purchase and install the activity, but also in terms of management education in how to actually conduct the activity. There may be a cultural environment built up around the activity.

It should be clear that the characteristics of use of diesel-powered pumping plants match the descriptions above.

Having established that the air quality problem from diesel-powered pumping plants is a non-point source problem, the question is how should this type of problem be addressed? NPS are substantially the result of management actions, either design, maintenance, or operational. Thus, if a non-point source problem is to be fixed, there must be a change in management action - people have to change the way they think and act.

Three things have to happen to make someone change in the context of solving some problem of behavior:

1. He/she must see that there is a problem and that that problem is their responsibility.

2. He/she must see that there are solutions available for the problem.

3. He/she must have resources to implement the solution.

Thus, programs that address non-point problems at the end-user level generally have three components. These three components exist at both the program design and the program implementation level. They are:

1. Problem awareness - At the implementation level the actors need to see that there is a genuine problem and that they are (wholly or partially) responsible for solving that problem. "Seeing" implies that the actor not only takes responsibility but also has tools by which specific problems can be identified. At the program design level it is essential managers a) identify the real (or priority) problem(s), b) implement sufficient education and public outreach, and c) ensure that engineering/analysis tools are available for individual problem identification.

2. Solution awareness - At the implementation level the actors need to see that there are solutions to the problem(s)- that is, something can be done. At the program design level it is essential that managers identify viable solutions ("targeted technologies"). Viability means more than just the ability to improve energy efficiency. It must be economical, reliable, practical, widely adaptable in the field, and understandable.

3. Resources - At the implementation level the actors need the time, money, and expertise to a) identify their problem(s), b) identify the most applicable solution(s), and c) install the solution(s). It is essential that program designers recognize when aide in the form of engineering services, low interest loans, and outright grants are required.

To paraphrase the above discussion: if a manager doesn't see a problem, or doesn't believe it is his/her problem, nothing will change – we need problem awareness. If the manager sees the problem but doesn't see that there is anything that can be done, nothing will change – we need solution awareness. However, even if the manager sees the problem and has a solution, nothing will be done unless resources are available to implement the solution.

III.2 Required Components

We see three required components to the proposed DPEP:

1. Education – this will be used to install both Problem Awareness and Solution Awareness. Problem Awareness will include statistics from our current pump test database (i.e. many pumping plants are inefficient) and air quality statistics (i.e. the problem is real and is really physically harming people, animals, and plants). Solution Awareness will include the value of the pump efficiency test, how to specify and maintain an efficient pumping plant, how to know how much water to pump, and the importance of a flow meter to know how much water has been pumped.

CIT currently utilizes its two Mobile Education Centers (MECs) to present educational seminars as part of the Agricultural Pumping Efficiency Program (see www.pumpefficiency.org). The two MECs (also developed by CIT) are twenty-eight foot (28') gooseneck trailers that are self-contained, pumping plants. Figure 1 is a view of one of the MECs. As can be seen, the sides of the MEC open up to expose the equipment inside during educational seminars.

Equipment on board includes a generator, two types of pumps, a variable frequency drive, and flowmeters. The systems are instrumented and operating data is fed to a laptop computer and then projected on a screen for seminar attendees. The MECs are used to demonstrate pump performance curves, pump efficiency at different operating conditions, proper placement of flow meters, operations and economics of variable frequency drives (VFD), electric motor efficiency, and various other aspects of pump operation. The VFDs allow the simulation of an internal combustion engine as it provides for varying the motor speed.

Figure 1 – View of Mobile Education Center showing vertical turbine and horizontal centrifugal pumps and the generator powering the pumps.

2. Information – in the form of a subsidized pump efficiency test. As noted above, management has to accept there is a general problem, but also has to take responsibility for the problem. This will only happen if confronted with information concerning their operations. The pump efficiency test will provide that information but it is not now common for diesel-powered pumps to be tested. The DPEP will not only encourage the use of pump efficiency tests but is also intended to encourage the growth of a pump-testing industry for diesel-powered pumps.

   IMPORTANT! *- There are two basic reasons why a pump is inefficient, 1) it has physically deteriorated and/or 2) it is not suitable to the required operating condition (i.e. the required* *combination of flow and water pressure). This analysis has focused on the case of a worn pump. However, the pump efficiency test is also useful for identifying a pump that is not suitable for the required operating condition. This may have occurred because the pump was specified incorrectly to begin with, there was a change in the irrigation system, or possibly there was a systemic change in the groundwater level (in the case of a water well). In any case we expect DPEP to also address and improve pumping efficiency in these situations.*

Currently CIT maintains a list of over 40 approved pump test companies. These are companies that can satisfy written criteria regarding their experience, education, and tools. They also sign Professional Services Agreements with CIT whereby they agree to the use of our software for standardized calculations and reports, which include a pumping cost analysis, to the pump owners. Appendix 1 is an example pump test report from the current Agricultural Pumping Efficiency Program.

3. Targeted Resources – in the form of the Incentive Rebate. Agriculture as a whole acts as the result of combined experience. For example, drip tape as a form of irrigation was utilized in the early 1980's. However, it wasn't until the mid-1990's that the collective experience coalesced to a general acceptance of the practice. The proposed DPEP is intended to affect the "early adapters" of agriculture- that is, those farmers who are willing to try new practices. It is intended that their experiences with the DPEP and the actual in-field measured results, appropriately publicized, will move the broad agricultural community. And, as noted earlier, we expect the need for a DPEP to decrease as the broad agricultural community accepts and utilizes improved management and equipment.

   Currently, the average rebate per project for pumps of 50-150 horsepower in the Agricultural Pumping Efficiency Program is $3,412. If applied against the NOx savings expected the proposed DPEP would deliver NOx emissions reduction at the rate of $955/ton.

IV. The Center for Irrigation Technology

The Center for Irrigation Technology (CIT) is part of the College of Agricultural Sciences and Technology on the campus of California State University, Fresno. CIT has developed and implemented energy efficiency programs with a total of $17.8 million in funding since June, 2001 for both the California Energy Commission (CEC) and the California Public Utilities Commission (CPUC). It currently manages the Agricultural Pumping Efficiency Program (APEP) funded to a total of $9.1 million for the CPUC.

CIT also maintains a hydraulic testing laboratory and performs research in areas such as dairy lagoon emissions, use of electromagnetic inductance techniques for soil salinity mapping, bio-diesel, solar, and advanced irrigation management including air injection into buried drip tape irrigation systems as a means of improving crop yields.

The proposed DPEP is an extension of our current APEP. APEP addresses electric and natural gas-powered pumping plants only, and only within the service areas of the four major investor-owned utilities (PG&E, SCE, SCG, and SDG&E). APEP also offers subsidized pump efficiency tests (currently over 7,300), incentive rebates for pump retrofit/retrofit projects (currently over 465), and an extensive field education effort (80 seminars plus an extensive list of printed materials). These results are in addition to 8,700 pump tests and 438 pump retrofits provided by the earlier Agricultural Peak Load Reduction Program that was also developed and implemented by CIT for the CEC. Visit www.pumpefficiency.org for complete information regarding the APEP and CIT and all educational materials.

It is also worth noting that the California Energy Commission has recently completed a major study identifying the importance of the link between energy use and water use in California. The DPEP and

APEP programs are designed to be multi-purpose in nature. That is, they address the resource management problems of energy conservation, water conservation, and air quality with one program. In doing so they:

1. Leverage available resources among state and federal funding agencies.

2. Prevent or minimize re-directed impacts (i.e. don't fix something "here" that will make things worse "there).

3. Reduce confusion in the field as farmers and pump operators are presented with one program instead of many.

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