THE DEVELOPMENT OF A WATER MANAGEMENT STRATEGY FOR AN OPERATING BWR

by

M. W. Granus - Pennsylvania Power & Light Company
J. N. Vance - Impell Corporation

ABSTRACT

During plant refueling shutdowns and start-ups, large quantities of water are: (a) transferred to fill refueling cavities for refueling operations and subsequently drained for power operation, (b) drained from equipment and components during the outage for maintenance on plant equipment and (c) generated from thermal expansion of the reactor water. In addition, off-standard or out-of-spec. water may need to be stored to allow processing at some future time when adequate processing capacity exists. These water inventory shifts and processing requirements contribute to an overall water management problem.

Water for filling operations must be either supplied from plant water recycle storage tanks or be supplied as freshly treated water from the make-up water treatment system. For equipment and cavity drain downs water must be processed and either stored in plant storage tanks or discharged from the plant. Off-standard water must be stored and processed. These water management operations place heavy processing demands on water treatment and waste processing systems and give rise to potential plant upsets caused by off-standard water or unavailable storage and treatment capacity.

This paper describes a water management strategy which was developed for an operating BWR. The strategy involves maintaining minimum acceptable tank inventories during operation, maximum utilization of in-plant stored water inventories and maximum usage of in-plant water processing equipment. Minimum acceptable water inventories are maintained in such tanks as, waste water collector, sample and condensate storage tanks prior to entering a refueling period. This allows for maximum storage volume for water drain downs during and following the refueling and for the storage of off-standard water. To monitor minimum tank inventories throughout the plant and to optimize radwaste processing capabilities, a computerized water tracking system was conceived, utilizing existing instrumentation to a maximum extent, for implementation.

BACKGROUND

Historically, boiling water reactors have had problems with water management. These problems have been characterized by excessive river discharges which result in an incrementally larger population doses and by the generation of large amounts of solid radwaste, because of the larger demands put upon water processing equipment. As a result, an effective water management strategy must be put in place in order to minimize these esoteric and economic penalties. An effective program for water management must be able to track and balance influent and effluent during normal operation as well as be sufficiently flexible in order to respond to these upset conditions brought on by startup, shutdown, and refueling.

The strategy described on this paper was developed for a two-unit 1050 MWe BWR with a Mark II containment. The water processing systems are characterized by the presence of seven deep-bed condensate polishers and powdered ion-exchange RWCU and fuel pool demineralizers. The radwaste system is comprised of a common collection system, two centrifugal precoat filters with a common deep-bed demineralizer and two submerged tube evaporators.

STRATEGY DESCRIPTION

The particular strategy described in this case is predicated upon the use of a minimum water inventory approach whose ultimate goal is to maximize the use of in-plant process water while minimizing the use of make-up capability and releases to the environment.

Before implementing such a strategy, certain prerequisites must be applied. First, water within the process boundary must be kept reasonably clean. That is, those areas where, in the past little attention was paid to water quality, must now be clean. A prime concern is the suppression pool. It must be cleaned on a periodic basis and always before a refueling. This can be done by recirculating the pool on the spare condensate polisher or in the cases where additional pool clean-up capability is provided, the pool should remain clean. Secondly, while the strategy can be applied to any situation, its use is made easier by reducing the normal daily influent to the radwaste collection system to as low a level as can be achieved. In order to do so, surveillance and correction of packing and seal leakage must be implemented and maintained. This effort can also be augmented by frequent sump surveillance.

The strategy begins by first monitoring the station water inventory on a daily basis. This can be accomplished by various manual and computer assisted methods. Typical data points for the support of this effort are depicted in Table 1.

TABLE I

Demineralized Water Usage	Pump Run Time
Reactor Building Sump	Pump Run Time
Turbine Building Sump (outer)	Pump Run Time
Turbine Building Sump (central)	Pump Run Time
Turbine Building Sump (condenser area)	Pump Run Time
Radwaste Building Sump	Pump Run Time
CST	Level Change
Hotwell	Level Change
Suppression Pool	Level Change
Refueling Water Tank	Level Change
Radwaste Collection Tanks	Level Change
Radwaste Surge Tank	Level
Radwaste Sample Tank	Level
Evaporator Distillate Tank	Level
Laundry Drain Tank	Pump Run Time
Laundry Drain Tank	Level
Laundry Sample Tank	Level
Chem Waste Tank	Level
Phase Separator RWCU	Pump Run Time
Phase Separator Waste Sludge	Pump Run Time
*Rate of Change of On Service RW Collector Tank	Plot
*Rate of Change of On Service Chem Waste Tank	Plot
Total Demin Water Added to Plant/24Hours	Cal
Total Liquid Radwaste Collected/24 Hours	Cal
Total Liquid Radwaste Processed/24 Hours	Cal
Total Liquid Radwaste Reprocessed/24 Hours	Cal
Total Liquid Radwaste Returned to Process/24 Hours	Cal
Total Liquid Radwaste Discharged to River/24 Hours	Cal
Total Liquid Radwaste Discharged to Chem Waste/24 Hours	Cal
Total Evaporator Distillate Returned to Process/24 Hours	Cal

* Plot Hourly

The next phase of the strategy is to apply the concept of using process water for all evolutions so as to maintain a constant water inventory that may vary only because of leakage. This leakage would then be collected and returned to the process. In applying this concept within the framework of the previously described minimum water inventory, sufficient surge capacity is now provided within the system to allow for the storage, and later reprocessing, of water that does not meet reactor standards. In addition, if due to maintenance, process water must be drained to radwaste, it is done in a manner that sends the water directly to an empty collection tank without any additional impacts to the collection system in progress. Upon completion of the transfer, the process water is isolated, sampled, and returned to a process vessel.

Prior to refueling, the minimum inventory concept is again applied and the flow guide is used to determine what water should be used for filling the reactor cavity. In lieu of using water from the condensate or refueling water storage tanks, the reactor cavity can be filled by using water from the suppression pool as there are no Technical Specification requirements for suppression pool level during refueling. If this water has not been sufficiently cleaned using the spare condensate polisher prior to shutdown, it can be cleaned fairly rapidly after flooding using either the condensate or fuel pool clean-up systems. Additional water, if required, can be taken from the condenser hotwell or the condensate storage tank.

A similar approach to that of refueling can be applied to all water movements within the process boundary. By using the flow guide, pre-planning for routine maintenance can be achieved, and surges into the collection system can be managed with a minimal impact upon radwaste and station operation. Although initially a manual method, the guide could be augmented by computer assistance that could provide for data collection, graphic flow paths, cost information, and real time evaluations of storage availability.

STRATEGY DEVELOPMENT

Recognizing that improper water management during plant operation and during refueling shutdowns and startups could jeopardize plant operation because of the unavailability of adequate water storage and processing capacity, the need for an overall water management strategy was identified. It was also recognized that the elements in the strategy development would apply to all plant conditions and consequently a single water management strategy could be developed.

The strategy development included the identification of:

(a) Minimum plant water inventory requirements; (b) Plant water storage locations (in and out); (c) Processing requirements for all systems; (d) Processing system characteristics and capacities; (e) All system cross-ties and interconnections; (f) Available transfer paths; (g) Specific water management strategies to accomodate specific plant conditions. In addition, means were identified to routinely monitor important plant characteristics, such as tank inventories, sump pump run times and radwaste performance parameters.

The first step taken in the strategy development was to identify the minimum water inventory requirements for all plant operating conditions. This included the minimum water storage requirements for the condensate storage tanks, suppression pool, condenser hotwell, refueling water storage tanks and refueling water cavities. This established the boundary operating conditions and water transfer requirements. Then all potential water storage locations were identified. This included all radwaste tankage, suppression pool, condenser hotwell, refueling cavities, and the refueling water and condensate storage tanks.

The plant water storage locations were identified as potential uses for the storage of off-standard water during normal power operation, for the storage of refueling and equipment drain down water and as a source of water for filling the refueling cavities. Table II lists typical water storage inventories.

TABLE II

Typical BWR Water Storage Inventories

(Two Unit Station)

	Capacity Gallons	Startup Inventory Gallons	Operating Inventory Gallons	Refueling Outage Unit Inventory	Operating Unit Inventory
Demin. Water Makeup Tank	50,000	50,000	50,000		50,000
Refueling Water Tank	680,000	0	0		0
CST	(2) 300,000	(2) 300,000	(2) 231,000	200,000	231,000
Hotwell	(2) 238,000	(2) 23,500	(2) 148,000	0	148,000
Reactor Vessel	(2) 176,000	(2) 176,000 (cold)	(2) 104,000	157,000	104,000
Steam Lines	(2) 7,000	(2) 7,000	(2) 0	7,000	0
Cask Pit	60,000	0	0		0
Dryer/Separator Pit	(2) 340,000	(2) 0	(2) 0	Cavity 240,000+340,000	0
Fuel Pool	(2) 340,000	(2) 340,000	(2) 340,000	340,000	34,000
Radwaste Collection TKs	66,000	0	42,000		42,000
Radwaste Surge TKs	44,000	0	0		0
Radwaste Sample TKs	66,000	0	0		0
Radwaste Sumps	23,000	2,300(10%)	2,300		2,300
Evaporator Distillate TK	5,700	0	5,000		5,000
Suppression Pool	(2)1,394,000	(2) 984,000(1-1/2ft) high	(2) 984,000	523,000(661ft)	984,000
Total Capacity	6,584,700	3,713,300	3,713,300	3,713,300 .	

The third step was to identify all water processing requirements in the plant. This included the processing requirements for the radwaste treatment system, the fuel pool clean-up system, the condensate polishing system and the make-up demineralizer system. The processing requirements also included the clean-up required for the suppression pool and the refueling cavity drain down water.

The capacities and types of treatment (i.e. filtration, ion exchange, etc.) provided in the design for the above processing requirement were then identified. This is important for determining processing compatibility between systems to the extent that the systems are cross-tied. A unique feature of BWR's is that reactor water and other plant water systems contain no additives and consequently this allows considerable cross-sharing between systems. All cross-ties and piping interconnections between processing systems were identified using plant flow diagrams and P&ID's.

Once processing requirements had been identified, minimum water inventories established, and available water storage locations determined, then appropriate transfer paths were constructed for different potential plant conditions considering processing compatibilities and available cross-ties and interconnections. The transfer paths, water storage locations and available storage capacities were constructed on a total plant water flow diagram.

The next step in the strategy development was to identify ways and means in which the water inventory and radwaste treatment could be monitored. The aim of the monitoring is to anticipate plant events and system upsets, to identify appropriate processing equipment, to identify available storage locations and to generally optimize the radwaste system performance to keep tank levels at a minimum. For this strategy, important plant parameters such as tank levels, sump pump run times, and water chemistries were identified for routine monitoring and tracking on a fairly frequent basis. It was, of course, recognized that such a monitoring program is ideally suited for the application of real-time computer programs, although not mandatory.

A total plant water flow diagram for a typical BWR is shown in Fig. 1. From this and the routine monitoring of important plant parameters, specific water management strategies can be devised to account for virtually all plant conditions.

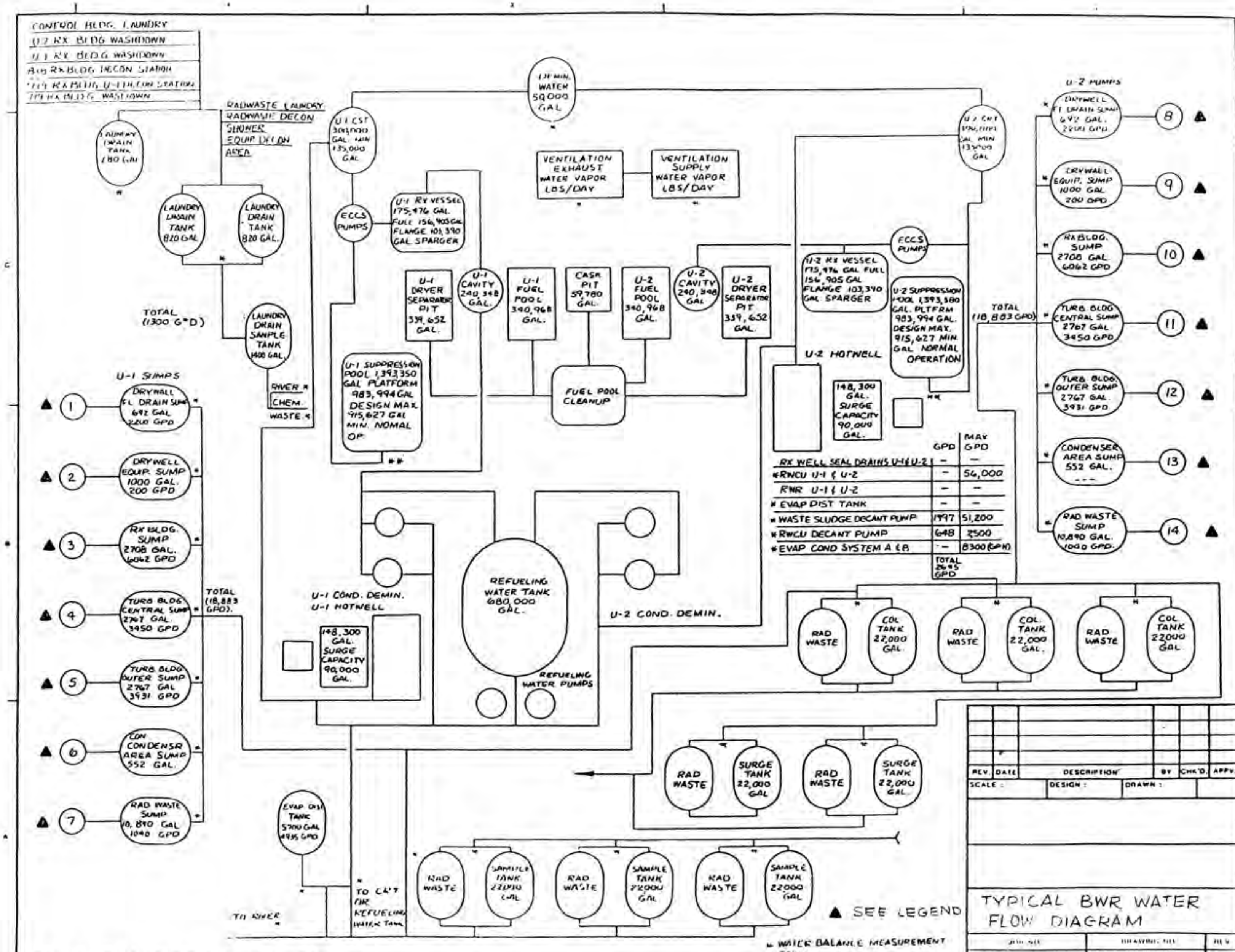

Fig. 1 Typical BWR Water Flow Diagram

Legend:

1. Vent cooler drains
   CRD flange leakage
   Chilled water drains
   Cooling water drains

2. Reactor recirculation pump cooler drains (M-143)
   RPV bottom drain
   Reactor head seal leakoff
   Bulkhead drain
   Bellows leakage drain
   RPV vent
   Recirculation pump seal leakoff

3. Charging water header drains
   Main steam valve leakage 400 GPD
   Reactor water clean-up 50 GPD recirc. pump seal leakage
   Reactor water clean-up regenerative heat exchanger
   Reactor water clean-up non-generative heat exchanger
   Reactor water clean-up holding pump
   Fuel pool heat exchanger shell drains
   Fuel pool cooling pump leakage and drains
   Dryer and storage pit drains
   Reactor well drain
   Fuel pool gate drain
   Reactor water clean-up backwash receiving tank
   Reactor building sample station 1440 GPD
   Reactor water clean-up precoat pump
   Suppression pool water filter pump drain
   Reactor building cooling water head tank
   CRD system floor drains
   Miscellaneous pump base plate drains
   Floor drains 2000 GPD
   Miscellaneous line vents and drains
   Reactor well, dryer separator storage pool and liner plate drains
   Reactor building cooling water heat exchanger and cooling water pump drains
   Reactor building washdown areas (El. 719'-1" only)
   CRD scram discharge head vent and drain
   Floor drains from refueling
   Floor washdown area El. 818'-1"
   Railroad unloading bay El. 670'-0"
   Floor drains from HV equip rm. 779'-1" and El. 799'-unit 1
   Core spray room A
   Core spray room B
   HPCI room
   IRHR room A
   IRHR room B
   RCIC room

4. Control rod drive pump & filter drains
   Feedwater htrs. 3-5 drains - tube side
   Feedwater htrs. 3-5 drains - shell side
   Condensate transfer pumps
   Miscellaneous line vents and drains
   Sample station 1440 GPD
   Refueling water pumps
   Turbine building chiller drains
   Condenser neck expansion joint drains
   Spray header drains
   Condensate pump packing overflow 960 GPD
   Main condenser waterbox vents
   Control rod drive vents and pump base plate drains 50 GPD
   Off-gas condenser tube drains
   Feedwater htrs. 3-5 vents - tube side
   Miscellaneous off-gas recombiner area drains
   Pump base plate drains
   Turbine building sample station
   Floor drains 100 GPD
   Condensate pump motor cooler drains
   Pipe tunnel sump
   Control building HV drains
   Turbine building HV drains

5. Feedwater htrs. 1 and 2 drains - tube side
   Feedwater htrs. 1 and 2 drains - shell side
   Drain coolers drains
   Miscellaneous line vents and drains
   Condenser neck expansion joint seals
   Spray header drains
   Main condenser waterbox drains
   Feedwater htrs. 1 and 2 vents - tube side
   Service and instrument air system drains (M-125)
   Moisture separator room flr. drains
   Drain coolers vents - tube side
   Centrifuge heavy - phase drains
   Pump base plate drains
   Floor drains 1000 GPD
   Turbine lo res rm drains
   Turbine building HV drains
   Turbine bearing drains
   Cond. demin. resin cleaner 2931

6. Cond. area drains

7. Liquid radwaste collection tanks - pumps
   Liquid radwaste collection tank overflow
   Liquid radwaste surge tank and pump
   Liquid radwaste surge tank overflow
   Liquid radwaste filter drains
   Liquid radwaste demin. drain
   Liquid radwaste sample tanks and pumps
   Liquid radwaste sample tank drain and overflow
   Radwaste building sample station drain
   Miscellaneous line vents and drains
   Floor drains 1000 GPD
   Spent resin tank drain and overflow
   Precoat. filter aid pumps and tanks
   Clean-up phase separators (M-144)
   Clean-up decant. and sludge discharge pumps
   Waste sludge phase separator (M-144)
   Waste sludge decant. and sludge discharge pumps
   RW building HV drains
   Off-gas system 40 GPD

8. Vent cooler drains
   CRD flange leakage
   Chilled water drains
   Cooling water drains

9. Reactor recirculation pump
   Cooler drains (M-143)
   RPV bottom drain
   Reactor head seal leakoff
   Bulkhead drain
   Bellows leakage drain
   RPV vent
   Recirculation pump seal leakoff

10. Charging water header drains
    400 GPD main steam valve leakage
    50 GPD reactor water clean-up
    Recirc. pump seal leakage
    Reactor water clean-up regenerative
    Heat exchanger
    Reactor water clean-up non-generative heat exchanger
    Reactor water clean-up holding pump
    Fuel pool heat exchanger shell drains
    Fuel pool cooling pump

Leakage and drains
Dryer and storage pit drains
Reactor well drain
Fuel pool gate drain
Reactor water clean-up
Backwash receiving tank
1440 GPD reactor building sample station
Reactor water clean-up precoat pump
Suppression pool water
Filter pump drain
Reactor building cooling water
Head tank
CRD system floor drains
Miscellaneous pump base plate drains
2000 GPD floor drains
Miscellaneous line vents and drains
Reactor well, dryer separator storage
Pool and liner plate drains
Reactor building cooling water heat
Exchanger and cooling water
Pump drains
Reactor building washdown areas
(El. 719'-1" only)
CRD scram discharge head
Vent and drain
Floor drains from refueling
Floor washdown area
El. 818'-1"
Railroad unloading bay
El. 670'-0"
Floor drains from HV equip. rm.
El. 779'-1" and El. 799'-Unit 1
Core spray room A
Core spray room B
HPCI room
IRHR room A
IRHR room B
RCIC room

11. Control rod drive pump and filter drains
Feedwater htrs. 3-5 drains - tube side
Feedwater htrs. 3-5 drains - shell side
Condensate transfer pumps
Miscellaneous line vents and drains
1440 GPD sample station
Refueling water pumps
Turbine building chiller drains
Condenser neck expansion
Joint drains
Spray header drains
960 GPD condensate pump packing overflow
Main condenser waterbox vents
Control rod drive vents - 50 GPD and pump base plate drains
Off-gas condenser tube drains
Feedwater htrs. 3-5 vents - tube side
Miscellaneous off-gas recombiner area drains
Pump base plate drains
Turbine building sample station
Floor drains 100 GPD
Condensate pump motor
Cooler drains
Pipe tunnel sump
Control building HV drains
Turbine building HV drains

12. Feedwater htrs. 1 and 2 drains - tube side
Feedwater htrs. 1 and 2 drains - shell side
Drain coolers drains
Miscellaneous line vents and drains
Condenser neck expansion
Joint seals
Spray header drains
Main condenser waterbox drains
Feedwater htrs. 1 and 2 vents - tube side
Service and instrument air system drains (M-125)
Moisture separator room flr. drains
Drain coolers vents - tube side
Centrifuge heavy - phase drains
Pump base plate drains
Floor drains 1000 GPD
Turbine lo res rm drains
Turbine building HV drains
Turbine bearing drains
Cond. demin. resin cleaner 2931

13. Cond. area drains

14. Liquid radwaste collection tanks - pumps
Liquid radwaste collection tank overflow
Liquid radwaste surge tank and pump
Liquid radwaste surge tank overflow
Liquid radwaste filter drains
Liquid radwaste demin. drain
Liquid radwaste sample tanks and pumps
Liquid radwaste sample tank drain and overflow
Radwaste building sample station drain
Miscellaneous line vents and drains
Floor drains 1000 GPD
Spent resin tank drain and overflow
Precoat filter aid pumps and tanks
Clean-up phase separators (M-144)
Clean-up decant. and sludge
Discharge pumps
Waste sludge phase separator (M-144)
Waste sludge decant. and sludge
Discharge pumps
RW building HV drains
Off-gas system 40 GPD