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November 17, 2009

NL-09-119

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Proposed License Amendment Regarding Diesel Generator Air Start Receiver Pressure
Indian Point Unit Numbers 2 and 3
Docket Nos. 50-247 and 50-286
License Nos. DPR-26 and DPR-64

Dear Sir or Madam:

Pursuant to 10 CFR 50.90, Entergy Nuclear Operations, Inc, (Entergy) hereby requests a License Amendment to Operating License DPR-26, Docket No. 50-247 for Indian Point Nuclear Generating Unit No. 2 (IP2) and to Operating License DPR-64, Docket No. 50-286 for Indian Point Nuclear Generating Unit No. 3 (IP3). The proposed amendment will revise the test acceptance criteria specified for the EDG air receiver pressure requirements. These changes in the air receiver criteria are proposed to correct identified non-conservatisms in the calculation of air pressure requirements. The proposed amendment will also revise the number of normal Emergency Diesel generator starts the air receiver is capable of providing.

Attachment 1 provides a description and assessment of the proposed change. The marked-up pages showing the proposed changes are provided in Attachment 2. The Bases and additional FSAR changes are provided in Attachment 3 for information. Referenced calculations are provided in Enclosures 1 and 2. A copy of this application and the associated attachments are being submitted to the designated New York State official in accordance with 10 CFR 50.91.

Entergy requests approval of the proposed amendment within 12 months and an allowance of 30 days for implementation. There are no new commitments being made in this submittal. If you have any questions or require additional information, please contact Mr. Robert Walpole, Manager, Licensing at (914) 734-6710.

A001
NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on 11/17/2009, 2009.

Sincerely,

JEP/sp

Attachments:
1. Analysis of Proposed Technical Specification / FSAR Changes Regarding Diesel Generator Air Start Receiver Pressure
2. Markup of Technical Specifications / FSAR Pages for Proposed Changes Regarding Diesel Generator Air Start Receiver Pressure
3. Markup of Technical Specification Bases / Additional FSAR Changes Associated with the Proposed Changes Regarding Diesel Generator Air Start Receiver Pressure

Enclosures
1. Indian Point Unit 2 Calculation IP-CALC-06-00329, Rev. 1, "Replacement of EDG Air Start Motors."
2. Indian Point Unit 3 Calculation IP-CALC-07-00021, Rev. 1, "Emergency Diesel Generator Starting Air System."

cc: Mr. John P. Boska, Senior Project Manager, NRC NRR DORL
Mr. Samuel J. Collins, Regional Administrator, NRC Region 1
NRC Resident Inspectors
Mr. Francis J. Murray, Jr., President and CEO, NYSERDA
Mr. Paul Eddy, New York State Dept. of Public Service

ATTACHMENT 1 TO NL-09-119

ANALYSIS OF PROPOSED TECHNICAL SPECIFICATION / FSAR CHANGES

REGARDING

DIESEL GENERATOR AIR START RECEIVER PRESSURE

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 and 3
DOCKET NOS. 50-247 and 50-286

1.0 DESCRIPTION

Entergy Nuclear Operations, Inc (Entergy) is requesting an amendment to Operating License DPR-26, Docket 50-247 for Indian Point Nuclear Generating Unit No. 2 (IP2), and Operating License DPR-64, Docket No. 50-286 for Indian Point Nuclear Generating Unit No. 3 (IP3). The proposed change will revise the air receiver limits specified in TS 3.8.3 for the EDG air receiver pressure. These changes in the air receiver criteria are proposed to correct identified non-conservatisms in the calculation of air pressure requirements. The proposed amendment will also revise the number of normal Emergency Diesel generator starts the air receiver is capable of providing.

The specific proposed changes are listed in the following section.

2.0 PROPOSED CHANGES

The proposed TS changes are as follows:

A. The TS air receiver criteria in Unit 2 TS 3.8.3, Condition F change is as follows:

"F. One or more DGs with starting air receiver pressure < 250 psig and ≥ 90 psig.
F.1 Restore starting air receiver pressure to ≥ 250 psig."

To

"F. One or more DGs with starting air receiver pressure < 255 psig and ≥ 215 psig.
F.1 Restore starting air receiver pressure to ≥ 255 psig."

B. The TS air receiver in Unit 2 SR 3.8.3.5 change is as follows:

"Verify each DG air start receiver pressure is ≥ 250 psig."

To

"Verify each DG air start receiver pressure is ≥ 255 psig."

C. The TS air receiver criteria in Unit 3 TS 3.8.3, Condition F change is as follows::

"F. One or more DGs with starting air receiver pressure < 250 psig and ≥ 90 psig.
F.1 Restore starting air receiver pressure to ≥ 250 psig."

To

"F. One or more DGs with starting air receiver pressure < 255 psig and ≥ 187 psig.
F.1 Restore starting air receiver pressure to ≥ 255 psig."

D. The TS air receiver in Unit 3 SR 3.8.3.5 change is as follows:

"Verify each DG air start receiver pressure is ≥ 250 psig."

To

"Verify each DG air start receiver pressure is ≥ 255 psig."

The proposed FSAR changes are as follows:

A. The FSAR change for Unit 2 is to Section 8.2.3.1 "Source Descriptions" on page 19 as follows:

"Each air receiver has sufficient storage for four normal starts."

To

"Each air receiver has sufficient storage for two normal starts."

B. The FSAR change for Unit 3 is to Section 8.2.3 "Emergency Power" on page 12 as follows:

"Each air receiver has sufficient storage for 4 starts."

To

"Each air receiver has sufficient storage for 3 normal starts."

The Technical Specification / FSAR markup pages for these changes are in Attachment 2. The associated Technical Specification Bases / additional FSAR changes (to be made after approval using the 10 CFR 50.59 process) are in attachment 3 for information.

3.0 BACKGROUND

Unit 2 TS 3.8.3, Condition F requires entry when the pressure in one or more EDG air receivers is less than 250 psig and equal to or greater than 90 psig. The action is to restore the starting air pressure to equal to or greater than 250 PSIG within 48 hrs. Bases for Condition F says "However, as long as the receiver pressure is ≥ 90 psig, there is adequate capacity for at least one normal start, and the DG can be considered OPERABLE while the air receiver pressure is restored to the required limit."

When reviewing Unit 2 calculation IP-CALC-06-00329, Rev 0 for replacement of the Emergency Diesel Generator (EDG) air start motors, Engineering determined that the TS were non-conservative because the lower limit of 90 psig was the minimum required air pressure at the air start motor during each start and did not consider pressure drop from the air receiver. This also made incorrect the Unit 2 FSAR and TS Bases which indicate each air receiver has sufficient storage for four normal starts. Additionally, all starting air will be consumed during a failed start attempt. This is due to overcrank relays which are set for about 15-17 seconds which is greater than the four starts of about 3 to 3.5 seconds.

An extent of condition review for Unit 3 was performed. Unit 3 TS 3.8.3, Condition F is similar. The TS condition requires entry when the pressure in one or more EDG air receivers is less than 250 PSIG and equal to or greater than 90 PSIG. The action is to restore the starting air pressure to equal to or greater than 250 PSIG within 48 hrs. It was determined that the TS were non-conservative because the lower limit of 90 psig was the minimum required air pressure at the air start motor during each start and did not consider pressure drop from the air receiver. The FSAR and TS Bases also indicate there is sufficient air for four normal starts which is incorrect. The overcrank relay, also set for about 15-17 seconds, will result in consumption of starting air if there is a failed start. This renders the Unit 3 TS Bases incorrect which indicate "Each DG has an air start system with adequate capacity for four successive start attempts on the DG without recharging the air start receiver(s). The air starting system is designed to shutdown and lock out any engine which does not start during the initial start attempt so that only enough air for one automatic start is used. This conserves air for subsequent DG start attempts."

NRC Administrative Letter 98-10 states that an inadequate TS value is considered a degraded condition under Generic Letter 91-18 (superseded by RIS 2005-20). Administrative controls are an acceptable interim corrective action and Administrative controls have been established at IPEC to assure the air receiver pressure is maintained within acceptable limits.

4.0 TECHNICAL ANALYSIS

The TS 3.8.3 states that with one or more EDG's with air receiver pressure less than 250 PSIG and equal to or greater that 90 PSIG then restore the starting air pressure to equal to or greater than 250 PSIG within 48 hrs.

For IP2, Calculation IP-CALC-06-00329 (Reference 1) evaluated the system and identified the required parameters for the TS as "One or more DGs with starting air receiver pressure < 255 psig and ≥ 215 psig." For IP3, Calculation IP-CALC-07-00021 (Reference 2) evaluated the system and identified the required parameters for the TS as "One or more DGs with starting air receiver pressure < 255 psig and ≥ 187 psig."

The calculations included the following design input and assumptions:

- The internal volume of the starting air system was assumed to be $49ft^3$ rather than the $53ft^3$ in the FSAR. This was the result of an internal calculation IP-CALC-08-00068 which established the volume as $49.3ft^3$.
- The average crank time is 3 to 3.5 seconds so a 4 second crank time was assumed.
- For IP2 the EDG lubricators require an average of 40 scfm to obtain the maximum drip so 20 scfm was assumed to be flowing through each starting air motor header. The IP3 lubricators are not required and there is no air flow.
- The redundant air starting motors each receives equal amounts of air each start.
- The pressure at the air motor inlet must be above 90 psig during a start in order to deliver 900 scfm of air on IP2 and 800 cfm of air on IP3. The flow differences are due to different air start motors and the IP2 lubricators.
- There are separate 30 gallon air receivers for the inlet and outlet louvers. These do not have to be supplemented by the air start receivers. The IP2 inlet and outlet dampers and the IP3 inlet dampers fail open on loss of air. The IP3 outlet dampers require air to remain open.

- The IP3 calculation considers the replacement of pressure switches that provide for signals to start the air start crank relay, the overcrank timer, the oil pressure timers, the jacket water pressure relay, the field flash shutdown relay, the jacket water pressure relay, the crankcase exhauster relay, and energize the pre-lube oil pump. These switches will be replaced due to problems with the existing switches and will have a higher setpoint for enhanced operation. This modification would affect the existing limits so it will be made after the proposed changes.

The IP2 calculation determined that the air receiver pressure must remain above 191.6 psia to ensure air pressure at the air start motor remains above 90 psig throughout the 4 second start. The calculation determined that the air receiver pressure dropped by approximately 38.2 psi on each start. The analytical limit on the air receiver is 255 psig so there is sufficient air for only two starts. The lower TS limit of 215 psig provides sufficient pressure for one start (191.6 psia -14.7 psig + 38.2 psig is 215.1 psig). The proposed FSAR change revises the text to indicate that 2 starts is the capacity of the air receivers. This will be corrected in the bases following approval of this change.

The IP3 calculation determined that the air receiver pressure must remain above 153 psig to ensure air pressure at the air start motor remains above 90 psig throughout the 4 second start. The calculation determined that the air receiver pressure dropped by 34 psig on each start. The analytical limit on the air receiver is 255 psig so there is sufficient air for only three starts. The lower TS limit of 187 psig provides sufficient pressure for one start (187 psig - 34 psig is 153 psig). The proposed FSAR change revises the text to indicate that 3 starts is the capacity of the air receivers. This will be corrected in the bases following approval of this change.

If an EDG does not start it will go into an overcrank condition. The Over Crank Timer (OCT) would allow the engine to crank for as long as 15-17 seconds. Based on this, the air pressure in the air receiver will drop below the pressure necessary to maintain the air start motor at 90 psig and the air left in the receiver after the over crank times out will not be sufficient for another EDG start. This over crank timer cannot be reduced because the reduction necessary to allow an additional start would be too close to the assumed normal start time of 4 seconds and may prematurely shutdown and lockout the engine during a normal start. This risk would not be warranted since the design function is to start the first time and reach the required speed within 10 seconds. The accident analyses did not credit the subsequent start of the diesels. Therefore the design remains capable of meeting the plant design bases. The Unit 3 Bases says "The air starting system is designed to shutdown and lock out any engine which does not start during the initial start attempt so that only enough air for one automatic start is used. This conserves air for subsequent DG start attempts." This will be corrected.

The starting air tanks are normally kept at a minimum pressure of approximately 275 psig. This is done by a low pressure switch that initiates the starting of the air compressor at approximately 275 psig. The compressor will keep running until tripped off by a signal from the high setpoint pressure switch at approximately 300 psi. The low pressure alarm, set to assure it alarms at the analytical limit of 255 psig alerts the operators to a possible low air condition per the alarm response procedure.

The changes to the minimum air pressure and the air pressure at which an alarm sounds are not accident initiators since they support a mitigation system. The changes do not significantly increase the consequences of an accident already evaluated since the values are intended to assure that a minimum of one air start is maintained in the air receivers and this function is still met. There are no equipment physical changes and no changes in the manner in which equipment is operated. There is no possibility of creating a new or different type of accident. The margin of safety is the ability to start two EDGs and bring them to rated speed and voltage within 10 seconds and there has been no change to this margin. The change is to the number of available air starts in the air receivers. The IP2 change from 4 to 2 starts and the IP3 change from 4 to 3 does not reduce the margin to safety because only one start has been postulated in the analyses of record and the OCT would have reduced the amount of air in the air receivers if it did not start. What is lost is some of the ability to attempt to restart the EDG after the initial event. If an EDG is manually stopped there may be air sufficient for one or two restarts. If air is exhausted due to the OCT when the EDG fails to start, the air compressors may be restarted if there is offsite power to run the compressor and no seismic event has caused loss of the compressor. Also, the manual cross connection capability still exists between trains.

5.0 REGULATORY ANALYSIS

5.1 No Significant Hazards Consideration

Entergy Nuclear Operations, Inc. (Entergy) has evaluated the safety significance of the proposed changes to the Indian Point 2 and 3 Technical Specifications and IP2 and IP3 FSARs which revise the TS pressure limits for the EDG air start receiver tank and revise the FSAR number of EDG normal air starts in the air receiver. The proposed changes have been evaluated according to the criteria of 10 CFR 50.92, "Issuance of Amendment". Entergy has determined that the subject changes do not involve a Significant Hazards Consideration as discussed below:

1. Does the proposed change involve a significant increase in the probability or consequences of an accident previously evaluated?

   No. The proposed change revises the pressure at which the Emergency Diesel generator (EDG) air receiver is required to be kept to meet surveillance requirements, revises the minimum EDG air receiver pressure required for one start of the EDG, and changes the number of normal starts in the air receiver. Revising the air receiver upper and lower pressure limits and reducing the number of starts in the air receiver are not accident initiators since an EDG is a mitigating system. Therefore the proposed changes do not increase the probability of an accident occurring. The proposed changes will assure that each EDG is capable of starting consistent with assumed accident analyses. These analyses assume that an EDG starts the first time and accident analyses do not credit subsequent starts. The proposed new TS limits on the EDG air receiver will assure that air pressure is adequate to assure one attempt to start the EDG is available at the lower limit and will provide additional normal starts at the upper pressure established in the surveillance. Establishing acceptance criteria that replace non conservative criteria and assure the design bases is met assures the capability of equipment to mitigate accident conditions. Therefore the proposed change does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the change create the possibility of a new or different kind of accident from any accident previously evaluated?

   No. The proposed change revises the pressure limit for the air receiver to initiate an alarm for low pressure, revises the lower pressure limit that must be maintained to assure that air is sufficient for at least one EDG start and revises the number of normal starts in the air receiver based on the revised calculations. The proposed change does not involve installation of new equipment or modification of existing equipment, so no new equipment failure modes are introduced. The proposed revision to the air receiver pressure limits and minimum air receiver EDG starts is also is not a change to the way that the equipment or facility is operated or analyzed and no new accident initiators are created. Therefore the proposed change does not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. Does the proposed change involve a significant reduction in a margin of safety?

   No. The conduct of surveillance tests, the conditions for failure of those tests and the number of EDG starts in the air receiver are means of assuring that the equipment is capable of maintaining the margin of safety established in the safety analyses for the facility. The proposed change in the EDG surveillance test acceptance criteria is consistent with values assumed in existing safety analyses which assume one start attempt for each EDG. The requirement for a minimum air pressure in the EDG air start receiver assures that there will be adequate air to allow at least one EDG start attempt which meets the intent of the existing TS. The reduction in the number of starts maintained in the air receiver does not affect the margins in accident analyses for this reason and because an EDG failure to start would reduce the air pressure below that required for one start before the overcrank timer would lock out a further start attempt. Therefore the proposed change does not involve a significant reduction in a margin of safety.

Based on the above, Entergy concludes that the proposed amendment to the Indian Point 2 and 3 Technical Specifications and FSARs presents no significant hazards consideration under the standards set forth in 10 CFR 50.92 (c), and, accordingly, a finding of "no significant hazards consideration" is justified.

5.2 Applicable Regulatory Requirements / Criteria

General Design Criterion (GDC) 17; "Electric Power Systems" requires that onsite electric power systems have sufficient independence, capacity, capability, redundancy, and testability to ensure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents, assuming a single failure.

GDC 18; "Inspection and Testing of Electric Power Systems" requires that electric power systems important to safety be designed to permit appropriate periodic inspection and testing to assess the continuity of the systems and the condition of their components.

IP2 Final Safety Analysis Report (FSAR) section 8.1 and IP3 FSAR section 1.3 describe how the requirements of GDC 17 and 18 are met at IP2 and IP3. Also, Technical Specification section

3.8.1 contains testing requirements for the EDGs and Technical Specification 3.8.3 contains pressure limits on the EDG air start receiver.

In the conversion to Improved Technical Specifications, Entergy adopted TS 3.8.3, Condition F which allowed the EDG to be considered operable when the air pressure was insufficient to perform the required 4 starts and allowed 48 hours to restore air pressure as long as it was maintained sufficient for one start. Revising the lower pressure limit assures that at least one start will be assured. Revising the upper limit provides the maximum capability for air starts at the analytical low pressure alarm limit. Revising the number of normal air starts in the air receivers reflects the design capability for original design.

5.3 Environmental Considerations

The proposed changes to the IP2 and IP3 Technical Specifications and FSARs do not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 PRECEDENCE

No specific precedent was identified for these changes. When non-conservative values are identified, NRC Administrative Letter 98-10 indicates that a revision to the TS should be processed to correct the condition.

7.0 REFERENCES

1. Indian Point Unit 2 Calculation IP-CALC-06-00329, Rev. 1, “Replacement of EDG Air Start Motors.”

2. Indian Point Unit 3 Calculation IP-CALC-07-00021, Rev. 1, “Emergency Diesel Generator Starting Air System.”

ATTACHMENT 2 TO NL-09-119

MARKUP OF TECHNICAL SPECIFICATION / FSAR PAGES FOR PROPOSED CHANGES

REGARDING DIESEL GENERATOR AIR START RECEIVER PRESSURE

Changes indicated by lineout for deletion and Bold/Italics for additions

Unit 2 Affected Pages:
TS 3.8.3-2 and 4
FSAR Chapter 8, Page 19

Unit 3 Affected Pages:
TS 3.8.3-2 and 4
FSAR Chapter 8, Page 12

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 and 3
DOCKET NOS. 50-247 and 50-286

ACTIONS (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
C. ---------------------------------- **- NOTE -** Only applicable in MODES 1, 2, 3 and 4. ---------------------------------- Total usable fuel oil in reserve storage tank(s) < 29,000 gal.	C.1	Declare all DGs inoperable.	2 hours
D. ---------------------------------- **– NOTE –** Only applicable to reserve fuel oil storage tanks in MODES 1, 2, 3 and 4. ---------------------------------- One or more DG fuel oil storage tanks or reserve fuel oil storage tanks with fuel oil total particulates not within limits.	D.1	Restore stored fuel oil total particulates to within limits.	7 days for DG fuel oil storage tank(s) <u>AND</u> 30 days for reserve fuel oil storage tank(s)
E. ---------------------------------- **– NOTE –** Only applicable to reserve fuel oil storage tanks in MODES 1, 2, 3 and 4. ---------------------------------- One or more DG fuel oil storage tanks or reserve fuel oil storage tanks with new fuel oil properties other than particulates not within limits.	E.1	Restore stored fuel oil properties to within limits.	30 days for DG fuel oil storage tank(s) <u>AND</u> 60 days for reserve fuel oil storage tank(s)
F. One or more DGs with starting air receiver pressure < ~~250~~ ***255*** psig and ≥ ~~90~~ ***215*** psig.	F.1	Restore starting air receiver pressure to ≥ ~~250~~ ***255*** psig.	48 hours

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.8.3.4	- NOTE - Only required to be met in MODES 1, 2, 3 and 4. Verify that fuel oil properties of new and stored fuel oil in the reserve storage tank(s) are within limits specified in the Diesel Fuel Oil Testing Program.	In accordance with the Diesel Fuel Oil Testing Program
SR 3.8.3.5	Verify each DG air start receiver pressure is ≥ ~~250~~ ***255*** psig.	31 days
SR 3.8.3.6	Check for and remove accumulated water from each fuel oil storage tank.	31 days

rpm, 3-phase, 60-cycle, 480-V generator. The units have a capability of 1750 kW (continuous), 2300 kW for 1/2 hour in any 24 hour period, and 2100 kW for 2 hours in any 24 hour period. There is a sequential limitation whereby it is unacceptable to operate EDG's for two hours at 2100 kW followed by operating at 2300 kW for a half hour. Any other combination of the above ratings is acceptable.

Any two units, backups to the normal standby AC power supply, are capable of sequentially starting and supplying the power requirement of at least one complete set of safeguards equipment. The units are installed in a seismic Class I structure located near the Primary Auxiliary Building.

Each emergency diesel is automatically started by two redundant air motors, each unit having a complete 53-ft^3 air storage tank and compressor system powered by a 480-V motor. The piping and the electrical services are arranged so that manual transfer between units is possible. The capability exists to cross-connect a single EDG air compressor to more than one (1) EDG air receiver, via manual air tie valves. However, to ensure that the operability of two (2) of the three (3) EDGs is maintained for minimum safeguards in the event of a single failure, administrative controls are in-place to require an operator to be stationed within the EDG Building, whenever any of the starting air tie valves are opened. Each air receiver has sufficient storage for ***two***~~four~~ normal starts. However, the diesel will consume only enough air for one automatic start during any particular power failure. Additionally, the engine control system is designed to shut down and lock out any engine that did not start during the initial try. The emergency units are capable of starting and load sequencing within 10 sec after the initial start signal. The units have the capability of being fully loaded within 30 sec after the start of load sequencing.

To ensure rapid start, the units are equipped with water jacket and lube-oil heating. A prelube pump circulates the oil when a unit is not running. The units are located in heated rooms.

Audible and visual alarms are located in the control room and in the diesel generator building. Alarms on the electrical annunciator panels in the control room are:

1. Diesel-generator trouble.
2. Diesel-generator oil storage tank low level.
3. 21 Diesel-Generator Trouble.
4. 22 Diesel-Generator Trouble.
5. 23 Diesel-Generator Trouble
6. Diesel-Generator Service Water Flow Low

The activation of the emergency diesel generator trouble alarm in the control room will be caused by the initiation of any of the following alarms in the diesel generator building:

1. Low oil pressure.
2. Differential fuel strainer, secondary.
3. Overcrank.
4. High differential lube-oil strainer.
5. High water temperature.
6. High differential pressure lube-oil filter.
7. High-high jacket water temperature.
8. Deleted.
9. Overspeed.
10. Overcurrent.
11. Low fuel oil level, day tank.
12. Reverse power.

ACTIONS (continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. ------NOTE--------- Only applicable in MODES 1, 2, 3 and 4. ------------------- Total useable fuel oil in reserve storage tank(s) < 26,826 gal.	C.1 Declare all DGs inoperable.	Immediately
D. One or more DG fuel oil storage tanks or reserve fuel oil storage tanks with fuel oil total particulates not within limits.	D.1 Restore fuel oil total particulates within limit.	7 days for DG fuel oil storage tank <u>AND</u> 30 days for reserve fuel oil storage tank
E. One or more DG fuel oil storage tanks or reserve fuel oil storage tanks with fuel oil properties other than particulates not within limits.	E.1 Restore fuel oil properties to within limits.	30 days for DG fuel oil storage tank <u>AND</u> 60 days for reserve fuel oil storage tank
F. One or more DGs with starting air receiver pressure < ~~250~~ ***255*** psig and ≥ ~~90~~ ***187*** psig.	F.1 Restore starting air receiver pressure to ≥ ~~250~~ ***255*** psig.	48 hours

(continued)

SURVEILLANCE REQUIREMENTS (continued)

	SURVEILLANCE	FREQUENCY
SR 3.8.3.4	---------------------NOTE--------------------- Only required in MODES 1, 2, 3 and 4. --- Verify that fuel oil properties in the reserve storage tank(s) are within limits specified in the Diesel Fuel Oil Testing Program.	In accordance with the Diesel Fuel Oil Testing Program
SR 3.8.3.5	Verify each DG air start receiver pressure is ≥ ~~250~~ ***255*** psig.	31 days
SR 3.8.3.6	Check for and remove accumulated water from each DG fuel oil storage tank.	92 days

The Authority submitted to the NRC its response to the SBO rule. The NRC responded by issuing a Safety Evaluation dated December 23, 1991 and a Supplemental Safety Evaluation dated June 8, 1992. Based on these safety evaluations, and IPN-94-127, dated October 13, 1994, the following SBO-related items are resolved:

1) Habitability of the areas from which the AFW flow control valves and steam generator PORVs are operated during the first hour after the onset of an SBO event was evaluated and determined acceptable.

2) In order to address the effects of loss of ventilation of the control room, control room cabinet doors will be opened within 30 minutes of the onset of an SBO event.

3) The containment Isolation Valve design and operation meets the intent of the guidance described in Regulatory Guide 1.155. Specific containment isolation valves which cannot be excluded based on the 5 criteria given in Regulatory Guide 1.155 are documented to justify their exclusion and ensure that containment integrity will be maintained during an SBO event.

4) All equipment required for response to an SBO shall be classified (at least) Category M, and included in the QA Program.

5) The EDG reliability program follows the guidance and meets the intent of Regulatory Guide 1.155. This program includes monitoring of EDG reliability, surveillance and testing of the EDGs, maintenance program, an information and data collection system and management oversight.

6) The coping duration categorization of IP3 has been revised from four to eight hours.

Any two emergency diesel generator units, as a backup to the normal standby AC power supply are capable of sequentially starting and supplying the power requirement of one minimum required set of safeguards equipment. The three units are located in a seismic Class I structure located near the Control Building.

Each emergency diesel is automatically started by two redundant air motors, each unit having a complete 53 cu ft air storage tank and compressor system powered from a 480 volt motor. The piping and the electrical services are arranged so that manual transfer between units is possible. Each air receiver has sufficient storage for ~~4~~***3*** starts. The diesel will consume, however, only enough air for one automatic start during any particular power failure. This is due to the engine control system which is designed to shutdown and lock out any engine which did not start during the initial try.

The emergency units are capable of being started and sequence load begun within 10 seconds after the initial signal. The starting system is completely redundant for each diesel generator. The units have the capability of being fully loaded within 30 seconds after the initial starting signal.

To ensure rapid start the units are equipped with water jacket and lube oil heating and pre-lube pump for circulation of lube oil when the unit is not running. The units are located in heated rooms.

ATTACHMENT 3 TO NL-09-119

MARKUP OF TECHNICAL SPECIFICATION BASES / ADDITIONAL FSAR CHANGES ASSOCIATED WITH THE PROPOSED CHANGES

REGARDING DIESEL GENERATOR AIR START RECEIVER PRESSURE

Changes indicated by lineout for deletion and Bold/Italics for additions

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 and 3
DOCKET NOS. 50-247 and 50-286

B 3.8 ELECTRICAL POWER SYSTEMS

B 3.8.3 Diesel Fuel Oil and Starting Air

BASES

BACKGROUND

Fuel oil for the three safeguards DGs is stored in the three DG fuel oil storage tanks (one tank associated with each DG) and the common DG fuel oil reserve.

The three DG fuel oil storage tanks are required to contain a minimum of 19,000 usable gallons (6334 gallons in the tank associated with each DG) to ensure that at least two of the three diesels can operate for at least 73 hours at the maximum load profile permitted by the diesels ratings. If the oil in one of the DG storage tanks is not available, there is sufficient fuel available to run two diesels for 45 hours at the maximum load profile permitted by the diesels ratings.

The DG fuel oil reserve is an additional 29,000 gallons of diesel fuel that is maintained in onsite storage tanks for the exclusive use of Indian Point 2 as described in UFSAR Section 8.2 (Ref. 1). This additional 29,000 gallons of diesel fuel is sufficient for operation of two diesels for an additional 111 hours at the maximum load profile permitted by the diesels ratings.

The basis for a minimum volume of diesel fuel oil of 48,000 gallons (i.e. 6334 usable gallons in each of the three DG fuel oil storage tanks and 29,000 gallons in the DG fuel oil reserve) is sufficient to operate two diesels for at least 168 hours at the maximum load profile permitted by the diesels ratings. If only two of the three DG fuel oil storage tanks are available, the total remaining fuel oil in storage is sufficient to provide for operation of two DGs at the maximum load profile permitted by the diesels ratings for a period of at least 160 hours. This volume of fuel oil is sufficient because commercial oil supplies and trucking facilities exist to ensure fuel oil deliveries within one day.

Note that the operators of Indian Point 2 are responsible for maintaining the reserve that is designated for Indian Point 3 use only as specified in the Indian Point 3 Technical Specifications at the location specified in the Indian Point 3 UFSAR. The DG fuel oil designated for Indian Point 3 is subject to the same sampling and testing requirements as the DG fuel oil designated for Indian Point 2. Indian Point 2 is responsible for promptly informing Indian Point 3 of the results of the periodic verification of DG fuel oil volume and the results of required DG sampling and testing.

BASES

BACKGROUND (continued)

Each of the three DG fuel oil storage tanks is provided with a motor-driven transfer pump mounted in a manhole opening above oil level. This pump is used to transfer fuel oil from the storage tank to the 175 gallon day tank supporting each DG. A decrease in day tank level to approximately 115 gallons (65%) will start the transfer pump in the corresponding DG fuel oil storage tank and run until the day tank is at approximately 158 gallons (90%). This process ensures that the day tank always contains sufficient fuel to support approximately 53 minutes of DG operation. If pump 21 fails to refill its associated day tank, transfer pump 22 will receive an automatic starting signal as a backup to the primary pump. In a similar manner, transfer pump 22 receives an automatic starting signal on low level in the day tank for diesel 22 and is backed up by transfer pump 23. Transfer pump 23 starts on low level in the day tank for diesel generator 23 and is backed up by transfer pump 21.

If the DGs require fuel oil from the fuel oil reserve tank(s), the fuel oil will be transported by truck to the DG fuel oil storage tanks. A truck with appropriate hose connections and capable of transporting oil is available either on site or at the Buchanan Substation. Commercial oil supplies and trucking facilities are also available in the vicinity of the plant.

For proper operation of the standby DGs, it is necessary to ensure the proper quality of the fuel oil. Regulatory Guide 1.137 (Ref. 2) addresses the recommended fuel oil practices as supplemented by ANSI N195 (Ref. 4). The fuel oil properties governed by these SRs are the water and sediment content, the viscosity, specific gravity (or API gravity), and impurity level. Requirements for DG fuel oil testing methodology, frequency, and acceptance criteria are maintained in the program required by Technical Specification 5.5.11, Diesel Fuel Oil Testing Program.

The DG lubrication system is designed to provide sufficient lubrication to permit proper operation of its associated DG under all loading conditions. The system is required to circulate the lube oil to the diesel engine working surfaces and to remove excess heat generated by friction during operation. Administrative controls ensure that the combination of the lube oil in the engine oil sump and maintained in onsite storage is sufficient to support 7 days of continuous operation of all three DGs. This supply is sufficient to allow operators to replenish the lube oil from offsite sources.

BASES

BACKGROUND (continued)

Each emergency diesel is automatically started by two redundant air motors. Each DG has a ***nominal*** ~~53~~***49*** ft^3 air storage tank and compressor system powered by a 480-V motor. The piping and the electrical services are arranged so that manual transfer between units is possible. The capability exists to cross-connect a single DG air compressor to more than one DG air receiver, via manual air tie valves. However, to ensure that the OPERABILITY of two of the three DGs is maintained in the event of a single failure, administrative controls are in-place to require an operator to be stationed within the DG Building, whenever any of the starting air tie valves are opened. Each air receiver has sufficient storage for four normal starts. However, all starting air will be consumed during a failed start attempt.

APPLICABLE SAFETY ANALYSES

The initial conditions of Design Basis Accident (DBA) and transient analyses in the UFSAR, Chapter 14 (Ref. 3), assume Engineered Safety Feature (ESF) systems are OPERABLE. The DGs are designed to provide sufficient capacity, capability, redundancy, and reliability to ensure the availability of necessary power to ESF systems so that fuel, Reactor Coolant System and containment design limits are not exceeded. These limits are discussed in more detail in the Bases for Section 3.2, Power Distribution Limits; Section 3.4, Reactor Coolant System (RCS); and Section 3.6, Containment Systems.

Since diesel fuel oil and the air start subsystem support the operation of the standby AC power sources, they satisfy Criterion 3 of 10 CFR 50.36(c)(2)(ii).

LCO

The basis for a minimum volume of diesel fuel oil of 48,000 gallons (i.e. 6334 usable gallons in each of the three DG fuel oil storage tanks and 29,000 gallons in the DG fuel oil reserve) is to provide for operation at the maximum load profile permitted by the diesels ratings for a period of at least 168 hours. If only two of the three DG fuel oil storage tanks are available, the total remaining fuel oil in storage is sufficient to provide for operation of two DGs at the maximum load profile permitted by the diesels ratings for a period of at least 160 hours. It is also required to meet specific standards for quality. This requirement, in conjunction with an ability to obtain replacement supplies within 7 days, supports the availability of DGs required to shut down the reactor and to maintain it in a safe condition for an anticipated operational occurrence (AOO) or a postulated DBA with loss of offsite power.

BASES

LCO (Continued)

In MODES 5 and 6, LCO requirements for DG fuel oil are relaxed in recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks. Therefore, the LCO requires a total of 6334 gallons of fuel oil in the tanks associated with the DGs that are required to be OPERABLE. This fuel may be stored in one tank associated with an OPERABLE DG or proportioned between the tanks associated with OPERABLE DGs. DG day tank fuel requirements, as well as transfer capability from the storage tank to the day tank, are addressed in LCO 3.8.1, "AC Sources - Operating," and LCO 3.8.2, "AC Sources - Shutdown."

The starting air system is required to have a minimum capacity for ~~four~~ ***two*** successive normal DG starts without recharging the air start receivers.

APPLICABILITY

The AC sources (LCO 3.8.1 and LCO 3.8.2) are required to ensure the availability of the required power to shut down the reactor and maintain it in a safe shutdown condition after an AOO or a postulated DBA. Since stored diesel fuel oil and the starting air subsystem support LCO 3.8.1 and LCO 3.8.2, stored diesel fuel oil and starting air are required to be within limits when the associated DG is required to be OPERABLE.

ACTIONS

The ACTIONS Table is modified by a Note indicating that separate Condition entry is allowed for each DG. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory actions for each inoperable DG subsystem. Complying with the Required Actions for one inoperable DG subsystem may allow for continued operation, and subsequent inoperable DG subsystem(s) are governed by separate Condition entry and application of associated Required Actions.

A.1

In this Condition, the requirements of SR 3.8.3.2.a are not met for one or more DG fuel oil storage tanks. This means that replenishment of DG fuel oil from the reserve storage tanks will be needed in less time than assumed in the UFSAR (Ref. 1). Therefore, the DG(s) associated with the DG fuel oil storage tank(s) not within limits must be declared inoperable within 2 hours because replenishment of the DG fuel oil storage tank requires that fuel be transported from the DG fuel oil reserve by truck and the volume of fuel oil remaining in the DG fuel oil storage tank may not be sufficient to allow

BASES

ACTIONS (continued)

continuous DG operation while the fuel transfer is planned and conducted under accident conditions.

This Condition is preceded by a Note stating that Condition A is applicable only in MODES 1, 2, 3 and 4. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks when in these MODES.

B.1

In this Condition, the requirements of SR 3.8.3.2.b are not met. With less than the total required minimum fuel oil in one or more DG fuel oil storage tanks, the two DGs required to be OPERABLE in MODES 5 and 6 and during movement of recently irradiated fuel may not have sufficient fuel oil to support continuous operation while a fuel transfer from the offsite DG fuel oil reserve or from another offsite source is planned and conducted under accident conditions.

This Condition requires that all DGs be declared inoperable immediately because minimum fuel oil level requirements in SR 3.8.3.2.b is a Condition of OPERABILITY of all DGs when in the specified MODES.

This Condition is preceded by a Note stating that Condition B is applicable only in MODES 5 and 6. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks when in these MODES.

C.1

In this Condition, the requirements of SR 3.8.3.1 are not met and the fuel oil remaining in the DG fuel oil reserve is not sufficient to operate 2 of the 3 DGs at the maximum load profile permitted by the diesels ratings for 7 days. Therefore, all 3 DGs are declared inoperable within 2 hours.

This Condition is preceded by a Note stating that Condition C is applicable only in MODES 1, 2, 3 and 4 because the DG fuel oil reserve is required to be available only in these MODES. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 and when moving irradiated fuel and, therefore, significantly reduces the amount of fuel oil required when in these MODES.

BASES

ACTIONS (continued)

D.1

This Condition is entered as a result of a failure to meet the acceptance criterion for total particulate concentration of the fuel oil in the DG fuel oil storage tanks and/or the DG fuel oil reserve storage tanks is not within the allowable value in Technical Specification 5.5.11, Diesel Fuel Oil Testing Program, during periodic verifications required by SR 3.8.3.3 and SR 3.8.3.4. Normally, trending of particulate levels allows sufficient time to correct high particulate levels prior to reaching the limit of acceptability. Poor sample procedures (bottom sampling), contaminated sampling equipment, and errors in laboratory analysis can produce failures that do not follow a trend. Since the presence of particulates does not mean failure of the fuel oil to burn properly in the diesel engine, and particulate concentration is unlikely to change significantly between Surveillance Frequency intervals, and proper engine performance has been recently demonstrated (within 31 days), it is prudent to allow a brief period prior to declaring the associated DG inoperable. The Completion Time to restore particulate levels to within required limits is 7 days for DG fuel oil storage tanks and 30 days for reserve storage tanks. These Completion Times allow for further evaluation, resampling and re-analysis of the DG fuel oil and recognize the time that may be required to restore parameters to within limits.

This Condition is preceded by a Note that clarifies that this Condition applies to the reserve fuel oil storage tanks only in MODES 1, 2, 3 and 4.

E.1

New fuel oil may be added to the DG fuel oil storage tanks or the reserve storage tanks before results of samples of this new fuel oil are available. If the properties of new fuel oil are determined not to be within the requirements established by Technical Specification 5.5.11, "Diesel Fuel Oil Testing Program," after the fuel oil has been added to the DG fuel oil storage tanks or the reserve storage tanks, then the oil in the affected storage tank(s) must be confirmed to be within the limits established by Technical Specification 5.5.11. A Completion Time of 30 days is permitted to confirm and/or restore the DG fuel oil storage tanks to within the limits of Technical Specification 5.5.11. A Completion Time of 60 days is permitted to confirm and/or restore the DG fuel oil reserve tanks to within the limits of Technical Specification 5.5.11.

BASES

ACTIONS (continued)

This Condition is preceded by a Note that clarifies that this Condition applies to the reserve fuel oil storage tanks only in MODES 1, 2, 3 and 4.

For the DG fuel oil storage tanks, this period provides sufficient time to test the stored fuel oil to determine that the new fuel oil, when mixed with previously stored fuel oil, remains acceptable, or to restore the stored fuel oil properties. This restoration may involve feed and bleed procedures, filtering, or combinations of these procedures. Even if a DG start and load was required during this time interval and the fuel oil properties were outside limits, there is a high likelihood that the DG would still be capable of performing its intended function.

For the DG fuel oil reserve, the properties of the fuel oil in the offsite reserve must be maintained within the limits established by Technical Specification 5.5.11, Diesel Fuel Oil Testing Program, because fuel oil from the offsite DG fuel oil reserve will be added to the DG fuel oil storage tanks within the first 48 hours following an event in conjunction with a sustained loss of offsite power. Failure to maintain the offsite DG fuel oil reserve within these limits may adversely impact DG operation of all three DGs at some point following addition of the reserves to the DG fuel oil storage tanks. Therefore, if the offsite DG fuel oil reserve is not restored to within these limits within the specified Completion Time, then all three DGs must be declared inoperable (Required Action E.1 applies to all three DGs).

Restoration of properties to within required limits may be performed by removing fuel or using the fuel in the gas turbine peaking units and replacing it with fuel within required limits or by the methods described for the DG fuel oil storage tank.

The Completion Time of 60 days for the restoration of fuel oil properties to within limits is acceptable because the DG fuel oil storage tanks contain sufficient fuel for a minimum of 48 hours DG operation at the maximum load profile permitted by the diesels ratings. The Completion Time is acceptable because there is a high likelihood that the DG would still be capable of meeting requirements for starting and endurance even if fuel oil from the DG fuel oil reserve must be added to the DG fuel oil tanks during the time interval the fuel oil properties are outside specified limits. Additionally, IP2 is located in an area where compatible fuel oil is readily available.

F.1

BASES

ACTIONS (continued)

With starting air receiver pressure < 25~~0~~***5*** psig, sufficient capacity for ***two***~~four~~ successive DG start attempts does not exist. However, as long as the receiver pressure is ≥ ~~90~~***215*** psig, there is adequate capacity for at least one normal start, and the DG can be considered OPERABLE while the air receiver pressure is restored to the required limit. A period of 48 hours is considered sufficient to complete restoration to the required pressure prior to declaring the DG inoperable. This period is acceptable based on the remaining air start capacity, the fact that most DG starts are accomplished on the first attempt, and the low probability of an event during this brief period. Entry into Condition F is not required when air receiver pressure is less than required limits while the DG is operating following a successful start.

G.1

With a Required Action and associated Completion Time not met, or one or more DG's fuel oil or starting air subsystem is not within limits for reasons other than addressed by Conditions A through F, the associated DG may be incapable of performing its intended function and must be immediately declared inoperable.

SURVEILLANCE REQUIREMENTS

SR 3.8.3.1

This SR provides verification that there is an adequate inventory of fuel oil in the DG fuel oil reserve to support 2 DGs at the maximum load profile permitted by the diesels ratings for 7 days assuming requirements for the DG fuel oil storage tanks and day tanks are met. The 7 day duration with 2 of the 3 DGs at the maximum load profile permitted by the diesels ratings is sufficient to place the unit in a safe shutdown condition and to bring in replenishment fuel from a commercial source.

This SR is modified by a Note that requires this SR to be met only when in MODES 1, 2, 3 or 4. The requirements for DG fuel oil are relaxed in recognition that in MODES 5 and 6 the reduced DG loading required to respond to events significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks.

BASES

SURVEILLANCE REQUIREMENTS (continued)

The 24 hour Frequency is needed because the DG fuel oil reserve is stored in fuel oil tanks that used to support the operation of gas turbine peaking units. This warrants frequent verification that required offsite DG fuel oil reserve volume is being maintained. Additionally, the DG fuel oil reserve includes oil designated for the exclusive use of Indian Point 3 and the IP3 UFSAR and the IP3 Technical Specifications require verification of the DG fuel oil reserve every 24 hours.

SR 3.8.3.2

SR 3.8.3.2.a provides verification when in MODES 1, 2, 3, and 4, that there is an adequate inventory of fuel oil in the DG fuel oil storage tanks to support at least 73 hours of operation at the maximum load profile permitted by the diesels ratings when all three DG fuel oil storage tanks are available or 45 hours of operation at the maximum load profile permitted by the diesels ratings when any two of the DG fuel oil storage tanks are available (Ref. 1). The 45 hour period of DG operation is sufficient time for a fuel transfer (from the fuel oil reserve or an offsite source) to be planned and conducted under accident conditions.

SR 3.8.3.2.b provides verification when in MODES 5 and 6 that the minimum required fuel oil for operation in these MODES is available in one or more DG fuel oil storage tanks. The minimum required volume of fuel oil takes into account the reduced DG loading required to respond to events in MODES 5 and 6 is sufficient to support the two DGs required to be operable in MODES 5 and 6 while a fuel transfer from the offsite DG fuel oil reserve or from another offsite source is planned and conducted under accident conditions.

This minimum volume required by SR 3.8.3.2.a and SR 3.8.3.2.b is the usable volume and does not include allowances for fuel not usable due to the fuel oil transfer pump cutoff switch (approximately 700 gallons). Additionally, an allowance must be made for instrument accuracy depending on the method used to determine tank volume. These adjustments must be made for each tank for SR 3.8.3.2.b if the required volume is found in more than one DG fuel oil storage tank.

The 31 day Frequency is adequate to ensure that a sufficient supply of fuel oil is available, since low level alarms are provided and unit operators would be aware of any large uses of fuel oil during this period.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.8.3.3 and SR 3.8.3.4

SR 3.8.3.3 requires that fuel oil properties of new and stored fuel oil in the DG fuel oil storage tanks are tested and maintained in accordance with Technical Specification 5.5.11, " Diesel Fuel Oil Testing Program."

SR 3.8.3.4 requires that fuel oil properties of new and stored fuel oil in the reserve storage tank(s) are within limits specified in Technical Specification 5.5.11. SR 3.8.3.4 is modified by a Note that requires this SR to be met only when in MODES 1, 2, 3 or 4 because the fuel oil in the reserve storage tank(s) is required only when in those MODES.

These Surveillances verify that the properties of new and stored fuel oil meet the acceptance criteria established by Technical Specification 5.5.11, "Diesel Fuel Oil Testing Program." Sampling and testing requirements for the performance of diesel fuel oil testing in accordance with applicable ASTM Standards are specified in the administrative program developed to ensure that Technical Specification 5.5.11 is met.

As required by Technical Specification 5.5.11, new fuel oil is sampled prior to addition to the DG fuel oil storage tanks and stored fuel oil is periodically sampled from the DG fuel oil storage tanks. Requirements and acceptance criteria for fuel oil are divided into 3 parts as follows:

a) tests of the sample of new fuel and acceptance criteria that must be met prior to adding the new fuel to the DG fuel oil storage tanks;

b) tests of the sample of new fuel that may be completed after the fuel is added to the DG fuel oil storage tanks; and,

c) tests of the fuel oil stored in the DG fuel oil storage tanks.

These tests are a means of determining whether new fuel oil is of the appropriate grade and has not been contaminated with substances that would have an immediate, detrimental impact on diesel engine combustion. If results from these tests are within acceptable limits, the fuel oil may be added to the storage tanks without concern for contaminating the entire volume of fuel oil in the storage tanks. These tests are to be conducted prior to adding the new fuel to the storage tank(s), but in no case is the time between receipt of new fuel and conducting the tests to exceed 31 days. The tests, limits, and applicable ASTM Standards are performed in accordance with the administrative program developed to ensure that Technical Specification 5.5.11 is met.

BASES

SURVEILLANCE REQUIREMENTS (continued)

Failure to meet any of the Specification 5.5.11 limits is cause for rejecting the new fuel oil, but does not represent a failure to meet the LCO because the fuel oil is not added to the storage tanks.

The tests of the sample of new fuel that may be completed after the fuel is added to the DG fuel oil storage tanks must be completed within 31 days. The fuel oil is analyzed to establish that the other properties of the fuel oil meet the acceptance criteria of Technical Specification 5.5.11. The 31 day period is acceptable because the fuel oil properties of interest, even if they were not within stated limits, would not have an immediate effect on DG operation. Failure to meet the specified acceptance criteria requires entry into Condition D and restoration of the quality of the fuel oil in the DG fuel oil storage tank within the associated Completion Time and explained in the Bases for Condition D. This Surveillance ensures the availability of high quality fuel oil for the DGs.

The periodic tests of the fuel oil stored in the DG fuel oil storage tanks verify that the length of time or conditions of storage has not degraded the fuel in a manner that could impact DG OPERABILITY. Fuel oil degradation during long term storage shows up as an increase in particulate, due mostly to oxidation. The presence of particulate does not mean the fuel oil will not burn properly in a diesel engine. The particulate can cause fouling of filters and fuel oil injection equipment, however, which can cause engine failure.

Particulate concentrations must meet the acceptance criteria of Technical Specification 5.5.11. It is acceptable to obtain a field sample for subsequent laboratory testing in lieu of field testing.

The Frequency of this test takes into consideration fuel oil degradation trends that indicate that particulate concentration is unlikely to change significantly between Frequency intervals.

SR 3.8.3.5

This Surveillance ensures that, without the aid of the refill compressor, sufficient air start capacity for each DG is available. The system design requirements provide for a minimum of ~~four~~***two*** engine normal starts without recharging. However, all starting air will be consumed during a failed start attempt. The pressure specified in this SR is intended to reflect the lowest value at which the ~~four~~***two normal*** successful starts can be accomplished.

BASES

SURVEILLANCE REQUIREMENTS (continued)

The 31 day Frequency takes into account the capacity, capability, redundancy, and diversity of the AC sources and other indications available in the control room, including alarms, to alert the operator to below normal air start pressure.

SR 3.8.3.6

Microbiological fouling is a major cause of fuel oil degradation. There are numerous bacteria that can grow in fuel oil and cause fouling, but all must have a water environment in order to survive. Removal of water from the fuel storage tanks once every 31 days eliminates the necessary environment for bacterial survival. This is the most effective means of controlling microbiological fouling. In addition, it eliminates the potential for water entrainment in the fuel oil during DG operation. Water may come from any of several sources, including condensation, ground water, rain water, and contaminated fuel oil, and from breakdown of the fuel oil by bacteria. Frequent checking for and removal of accumulated water minimizes fouling and provides data regarding the watertight integrity of the fuel oil system. The Surveillance Frequencies are consistent with Regulatory Guide 1.137 (Ref. 2). This SR is for preventive maintenance. Unless the volume of water is sufficient that it could impact DG OPERABILITY, presence of water does not necessarily represent failure of this SR, provided the accumulated water is removed within 7 days of performance of the Surveillance.

REFERENCES

1. UFSAR, Section 8.2.
2. Regulatory Guide 1.137.
3. UFSAR, Chapter 14.
4. ANSI N195-1976, Appendix B.

rpm, 3-phase, 60-cycle, 480-V generator. The units have a capability of 1750 kW (continuous), 2300 kW for 1/2 hour in any 24 hour period, and 2100 kW for 2 hours in any 24 hour period. There is a sequential limitation whereby it is unacceptable to operate EDG's for two hours at 2100 kW followed by operating at 2300 kW for a half hour. Any other combination of the above ratings is acceptable.

Any two units, backups to the normal standby AC power supply, are capable of sequentially starting and supplying the power requirement of at least one complete set of safeguards equipment. The units are installed in a seismic Class I structure located near the Primary Auxiliary Building.

Each emergency diesel is automatically started by two redundant air motors, each unit having a complete ***49***~~53~~-ft^3 ***(approximate internal volume)*** air storage tank and compressor system powered by a 480-V motor. The piping and the electrical services are arranged so that manual transfer between units is possible. The capability exists to cross-connect a single EDG air compressor to more than one (1) EDG air receiver, via manual air tie valves. However, to ensure that the operability of two (2) of the three (3) EDGs is maintained for minimum safeguards in the event of a single failure, administrative controls are in-place to require an operator to be stationed within the EDG Building, whenever any of the starting air tie valves are opened. Each air receiver has sufficient storage for four normal starts. However, the diesel will consume only enough air for one automatic start during any particular power failure. Additionally, the engine control system is designed to shut down and lock out any engine that did not start during the initial try. The emergency units are capable of starting and load sequencing within 10 sec after the initial start signal. The units have the capability of being fully loaded within 30 sec after the start of load sequencing.

To ensure rapid start, the units are equipped with water jacket and lube-oil heating. A prelube pump circulates the oil when a unit is not running. The units are located in heated rooms.

Audible and visual alarms are located in the control room and in the diesel generator building. Alarms on the electrical annunciator panels in the control room are:

1. Diesel-generator trouble.
2. Diesel-generator oil storage tank low level.
3. 21 Diesel-Generator Trouble.
4. 22 Diesel-Generator Trouble.
5. 23 Diesel-Generator Trouble
6. Diesel-Generator Service Water Flow Low

The activation of the emergency diesel generator trouble alarm in the control room will be caused by the initiation of any of the following alarms in the diesel generator building:

1. Low oil pressure.
2. Differential fuel strainer, secondary.
3. Overcrank.
4. High differential lube-oil strainer.
5. High water temperature.
6. High differential pressure lube-oil filter.
7. High-high jacket water temperature.
8. Deleted.
9. Overspeed.
10. Overcurrent.
11. Low fuel oil level, day tank.
12. Reverse power.

13. Low start air pressure.
14. Exciter field shutdown.
15. High/Low lube-oil temperature.
16. High differential pressure primary filter.
17. Deleted.

The diesel-generator oil storage tank low level alarm will be energized on a low level in any one of the three fuel-oil storage tanks.

The alarms "21 Diesel-Generator Trouble", "22 Diesel-Generator Trouble", and "23 Diesel-Generator Trouble" located on Panel SG in the Central Control Room will be activated respectively by the following conditions at each EDG local control panel:

1. Loss of DC control power.
2. Engine control switch position (Off or Manual).
3. Breaker control switch position pulled-out [Note - the breaker control switch in the CCR will activate the "Safeguards Equipment Locked Open" alarm (Window 1-8 on Panel SB-1) in the CCR].
4. Engine stop solenoid energized.
5. Day tank level low, primary and backup fuel pump fails to start.
6. For 23 diesel-generator trouble only, loss of voltage on EDG 23 auxiliary load main feed.

There are six electrical contacts, each of which when activated will energize a diesel-generator lockout relay. This lockout relay will, in turn, cause a diesel to shut down if it is operating or will prevent the diesel from responding to an automatic emergency start signal. These contacts are activated by one of the following conditions:

1. Activation of the diesel emergency stop push-button in the diesel-generator building.

2. Activation of the overcurrent relay. A phase-to-phase fault or excessive loads on the diesel generator will operate this relay.

3. Activation of the reverse power relay.

4. Activation of the overcrank relay. If a diesel engine fails to attain speed within ***approximately 15*** ~~13~~ sec, this relay will be energized.

5. Activation of the overspeed relay. When the mechanical governor senses 1070 rpm, this relay will be energized.

6. Activation of the low oil pressure relay. This relay is energized by the coincident sensing of lube-oil pressure below 60 psi by two of the three oil pressure switches for each diesel. An oil pressure timer is set to allow 20 sec to pass before tripping the diesel engine lockout relay. This circuit is designed to provide sufficient time for the oil pressure to build up following an engine start.

A safety injection signal will prevent the first three conditions from energizing the diesel engine lockout relay and tripping the diesel generator. Activation of any one of the latter three relays will cause a diesel to stop even when a safety injection signal is present. Shutdown permits corrective action to be taken before the engine is damaged, and the diesel generator can then

B 3.8 ELECTRICAL POWER SYSTEMS

B 3.8.3 Diesel Fuel Oil and Starting Air

BASES

BACKGROUND

Fuel oil for the safeguards DGs is stored in three 7,700 gallon DG fuel oil storage tanks located on the south side of the Diesel Generator Building. The offsite DG fuel oil reserve is maintained in two 30,000 gallon tanks located in the Indian Point 1 Superheater Building and/or a 200,000 gallon tank in the Buchanan Substation which is located in close proximity to the IP3 site. The IP3 offsite fuel oil reserve is maintained by the operators of IP2, in accordance with formal agreements. The IP3 offsite DG fuel oil reserve is normally stored in the same tanks used to store the IP2 offsite DG fuel oil reserve.

Sufficient fuel for at least 48 hours of minimum safeguards equipment operation is available when any two of the DG fuel oil storage tanks are available and each contains 5,365 usable gallons of fuel oil. Additional margin is provided by 115 gallons of fuel oil in the DG day tank required by SR 3.8.1.4. The maximum DG loadings for design basis transients that actuate safety injection are summarized in FSAR 8.2 (Ref. 1). These transients include large and small break loss of coolant accidents (LOCA), main steamline break and steam generator tube rupture (SGTR).

The three DG fuel oil storage tanks are filled through a common fill line that is equipped with a truck hose connection and a shutoff valve at each tank. The overflow from any DG fuel oil storage tank will cascade into an adjacent tank. Each DG fuel oil storage tank is equipped with a single vertical fuel oil transfer pump that discharges to either the normal or emergency header. Either header can be used to fill the day tank at each diesel. Each DG fuel oil storage tank has an alarm that sounds in the control room when the level in the tank approaches the level equivalent of the minimum required usable inventory. Each tank is also equipped with a sounding connection and a level indicator.

(continued)

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BASES

BACKGROUND (continued)

Each emergency diesel is equipped with a 175-gallon day tank with an operating level that provides sufficient fuel for approximately one hour of DG operation. A decrease in day tank level to approximately 115 gallons (65% full) will cause the normal and emergency fill valves on that day tank to open and the transfer pump in the corresponding DG fuel oil storage tank to start. Once started, the pump will continue to run until that day tank is filled. However, any operating transfer pump will fill any day tank with a normal or emergency fill valve that is open. When a day tank is at approximately 158 gallons (90% full), a switch initiates closing of the day tank normal and emergency fill valves.

Technical Specifications require sufficient fuel oil to operate 2 of the 3 required DGs at minimum safeguards load for 7 days. The Technical Specification required volume of fuel oil includes the 26,826 gallons of usable fuel oil in the reserve tanks, and 10,730 usable gallons in two DG fuel oil storage tanks (assuming a failure makes the oil in the third DG fuel oil storage tank unavailable), without crediting the additional margin of 230 gallons in two day tanks (assuming a failure makes the oil in the day tank associated with the third DG unavailable).

If the DGs require fuel oil from the fuel oil reserve tank(s), the fuel oil will be transported by truck to the DG fuel oil storage tanks. A truck with appropriate hose connections and capable of transporting oil is available either on site or at the Buchanan Substation. Commercial oil supplies and trucking facilities are also available in the vicinity of the plant.

For proper operation of the standby DGs, it is necessary to ensure the proper quality of the fuel oil. Requirements for DG fuel oil testing methodology, frequency, and acceptance criteria are maintained in the program required by Specification 5.5.12, Diesel Fuel Oil Testing Program.

Each DG has an air start system with adequate capacity for ~~four~~***three normal*** successive start attempts on the DG without recharging the air start receiver(s). The air starting system is designed to shutdown and lock out any engine which does not start during the initial start attempt. ~~so that only enough air for one automatic start is used. This conserves air~~ ***This consumes enough air that the receiver must be refilled*** for subsequent DG start attempts.

(continued)

BASES

APPLICABLE SAFETY ANALYSES

The initial conditions of Design Basis Accident (DBA) and transient analyses in the FSAR, Chapter 14 (Ref. 3), assume Engineered Safety Feature (ESF) systems are OPERABLE. The DGs are designed to provide sufficient capacity, capability, redundancy, and reliability to ensure the availability of necessary power to ESF systems so that fuel, Reactor Coolant System and containment design limits are not exceeded. These limits are discussed in more detail in the Bases for Section 3.2, Power Distribution Limits; Section 3.4, Reactor Coolant System (RCS); and Section 3.6, Containment Systems.

Since diesel fuel oil and the air start subsystem support the operation of the standby AC power sources, they satisfy Criterion 3 of 10 CFR 50.36.

LCO

Stored diesel fuel oil is required to have sufficient supply for 7 days of operation for 2 of 3 DGs at minimum safeguards load. Fuel oil is also required to meet specific standards for quality. This requirement, in conjunction with an ability to obtain replacement supplies within 7 days, supports the availability of DGs required to shut down the reactor and to maintain it in a safe condition for an anticipated operational occurrence (AOO) or a postulated DBA with loss of offsite power. DG day tank fuel requirements, as well as transfer capability from the storage tank to the day tank, are addressed in LCO 3.8.1, "AC Sources – Operating," and LCO 3.8.2, "AC Sources – Shutdown."

The starting air system is required to have a minimum capacity for ~~four~~ ***three normal*** successive DG start attempts without recharging the air start receivers.

(continued)

BASES

APPLICABILITY

The AC sources (LCO 3.8.1 and LCO 3.8.2) are required to ensure the availability of the required power to shut down the reactor and maintain it in a safe shutdown condition after an AOO or a postulated DBA. Since stored diesel fuel oil and the starting air subsystem support LCO 3.8.1 and LCO 3.8.2, stored diesel fuel oil and starting air are required to be within limits when the associated DG is required to be OPERABLE.

ACTIONS

The ACTIONS Table is modified by a Note indicating that separate Condition entry is allowed for each DG. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory actions for each inoperable DG subsystem. Complying with the Required Actions for one inoperable DG subsystem may allow for continued operation, and subsequent inoperable DG subsystem(s) are governed by separate Condition entry and application of associated Required Actions.

A.1

In this Condition, the requirements of SR 3.8.3.2.a are not met. Therefore, a DG will not be able to support 48 hours of continuous operation at minimum safeguards load and replenishment of the DG fuel oil storage tanks will be required in less than 48 hours following an accident. The DG associated with the DG fuel oil storage tank not within limits must be declared inoperable immediately because replenishment of the DG fuel oil storage tank requires that fuel be transported from the offsite DG fuel oil reserve by truck and the volume of fuel oil remaining in the DG fuel oil storage tank may not be sufficient to allow continuous DG operation while the fuel transfer is planned and conducted under accident conditions.

This Condition is preceded by a Note stating that Condition A is applicable only in MODES 1, 2, 3 and 4. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks when in these MODES.

(continued)

BASES

ACTIONS (continued)

B.1

In this Condition, the requirements of SR 3.8.3.2.b are not met. With less than the total required minimum fuel oil in one or more DG fuel oil storage tanks, the one or two DGs required to be operable in MODES 5 and 6 and during movement of irradiated fuel may not have sufficient fuel oil to support continuous operation while a fuel transfer from the offsite DG fuel oil reserve or from another offsite source is planned and conducted under accident conditions. Fuel oil credited to meet this requirement must be in one or more storage tanks associated with the operable DG(s) because the fuel transfer pump in each tank may depend on power from that DG.

This condition requires that all DGs be declared inoperable immediately because minimum fuel oil level requirements in SR 3.8.3.2.b is a condition of Operability of all DGs when in the specified MODES.

This Condition is preceded by a Note stating that Condition B is applicable only in MODES 5 and 6 and during the movement of irradiated fuel. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required in the DG fuel oil storage tanks when in these MODES.

C.1

In this Condition, the fuel oil remaining in the offsite DG fuel oil reserve is not sufficient to operate 2 of the 3 DGs at minimum safeguards load for 7 days. Therefore, all 3 DGs are declared inoperable immediately.

This Condition is preceded by a Note stating that Condition D is applicable only in MODES 1, 2, 3 and 4 because the offsite DG fuel oil reserve is required to be available only in these MODES. This Note provides recognition that reduced DG loading required to respond to events in MODES 5 and 6 significantly reduces the amount of fuel oil required when in these MODES.

(continued)

ACTIONS (continued)

D.1

This Condition is entered as a result of a failure to meet the acceptance criteria of SR 3.8.3.3 or SR 3.8.3.4 when the DG fuel oil storage tanks or reserve storage tanks are verified to have particulate within the allowable value in Specification 5.5.12, Diesel Fuel Oil Testing Program. Normally, trending of particulate levels allows sufficient time to correct high particulate levels prior to reaching the limit of acceptability. Poor sample procedures (bottom sampling), contaminated sampling equipment, and errors in laboratory analysis can produce failures that do not follow a trend. Since the presence of particulates does not mean failure of the fuel oil to burn properly in the diesel engine, and particulate concentration is unlikely to change significantly between Surveillance Frequency intervals, and proper engine performance has been recently demonstrated (within 31 days), it is prudent to allow a brief period prior to declaring the associated DG inoperable. The 7-day and 30-day Completion Times, for the onsite tanks and the reserve storage tanks, respectively, allows for further evaluation, resampling and re-analysis of the DG fuel oil.

E.1

This condition is entered as a result of a failure to meet the acceptance criteria of SR 3.8.3.3 or SR 3.8.3.4 when the DG fuel oil storage tanks or reserve storage tanks are verified to have properties (other than particulates) within the allowable values of Specification 5.5.12, Diesel Fuel Oil Testing Program. A period of 30 days is allowed to restore the properties of the fuel oil in the DG fuel oil storage tank to within the limits established by Specification 5.5.12. This period provides sufficient time to test the stored fuel oil to determine that the new fuel oil, when mixed with previously stored fuel oil, remains acceptable, or to restore the stored fuel oil properties. This restoration may involve feed and bleed procedures, filtering, or combinations of these procedures. Even if a DG start and load was required during this time interval and the fuel oil properties were outside limits, there is a high likelihood that

(continued)

ACTIONS

E.1. (continued)

the DG would still be capable of performing its intended function. A period of 60 days is allowed to restore the properties of the fuel oil stored in the affected reserve storage tank to within the limits established by Specification 5.5.12. This period provides sufficient time to perform the actions described above for the DG fuel oil storage tanks. The additional time allowed for the reserve tanks is acceptable because reserve oil is not immediately needed to support DG operation and reserve oil is available from more than one reserve tank. Reserve oil is also available from commercial suppliers in the vicinity of the plant.

F.1

With starting air receiver pressure < ~~250~~***255*** psig, sufficient capacity for ~~four~~***three*** successive DG start attempts does not exist. However, as long as the receiver pressure is ≥ ~~90~~***187*** psig, there is adequate capacity for at least one start attempt, and the DG can be considered OPERABLE while the air receiver pressure is restored to the required limit. A period of 48 hours is considered sufficient to complete restoration to the required pressure prior to declaring the DG inoperable. This period is acceptable based on the remaining air start capacity, the fact that most DG starts are accomplished on the first attempt, and the low probability of an event during this brief period. Entry into Condition F is not required when air receiver pressure is less than required limits while the DG is operating following a successful start.

G.1

With a Required Action and associated Completion Time not met, or one or more DG's fuel oil or starting air subsystem not within limits for reasons other than addressed by Conditions A through F, the associated DG may be incapable of performing its intended function and must be immediately declared inoperable.

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.8.3.1

This SR provides verification that there is an adequate inventory of fuel oil in the offsite DG fuel oil reserve to support 2 DGs at minimum safeguards load for 7 days assuming requirements for the DG fuel oil storage tanks and day tanks are met. The 7 day duration with 2 of the 3 DGs at minimum safeguards load is sufficient to place the unit in a safe shutdown condition and to bring in replenishment fuel from a commercial source.

The 24 hour Frequency is needed because the DG fuel oil reserve is stored in fuel oil tanks that support the operation of gas turbine peaking units that are not under IP3 control. Specifically, the 26,826 gallons needed to support 7 days of DG operation is maintained in two 30,000 gallon tanks located in the Indian Point 1 Superheater Building and/or a 200,000 gallon tank in the Buchanan Substation. Although the volume of fuel oil required to support IP3 DG operability is designated as for the exclusive use of IP3, the fact that the oil in the storage tanks is used for purposes other than IP3 DGs and oil consumption is not under the direct control of IP3 operators warrants frequent verification that required offsite DG fuel oil reserve volume is being maintained.

SR 3.8.3.2

SR 3.8.3.2.a provides verification when in MODES 1, 2, 3, and 4, that there is an adequate inventory of fuel oil in the storage DG fuel oil tanks to support each DG's operation for at least 48 hours of operation of minimum safeguards equipment when any two of the DG fuel oil storage tanks are available and 5,365 gallons of usable fuel oil is contained in each tank.

SR 3.8.3.2.b provides verification when in MODES 5 and 6 and during movement of irradiated fuel that the minimum required fuel oil for operation in these MODES is available in one or more DG fuel oil storage tanks. The minimum required volume of fuel oil

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.8.3.2 (continued)

takes into account the reduced DG loading required to respond to events in MODES 5 and 6 is sufficient to support the two DGs required to be operable in MODES 5 and 6 and during movement of irradiated fuel while a fuel transfer from the offsite DG fuel oil reserve or from another offsite source is planned and conducted under accident conditions.

This minimum volume required by SR 3.8.3.2.a and SR 3.8.3.2.b is the usable volume and does not include allowances for fuel not usable due to the fuel oil transfer pump cutoff switch (worst case 956 gallons for #33 tank and 915 gallons for #31 and #32 tanks) and margin (20 gallons per tank). If the installed level indicators are used to measure tank volume, an additional allowance of 50 gallons for instrument uncertainty associated with the level indicators must be included. Appropriate adjustments are required for SR 3.8.3.2.b if the required volume is found in more than one DG fuel oil storage tank.

The 31 day Frequency is adequate to ensure that a sufficient supply of fuel oil is available, since low level alarms are provided and unit operators would be aware of any large uses of fuel oil during this period.

SR 3.8.3.3

This surveillance verifies that the properties of new and stored fuel oil meet the acceptance criteria established by Specification 5.5.12, "Diesel Fuel Oil Testing Program." Specific sampling and testing requirements for diesel fuel oil in accordance with applicable ASTM Standards are specified in the administrative program developed to ensure Specification.

New fuel oil is sampled prior to addition to the DG fuel oil storage tanks and stored fuel oil is periodically sampled from the DG fuel oil storage tanks. Requirements and acceptance

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.8.3.3 (continued)

criteria for fuel oil are divided into 3 parts as follows: a) tests of the sample of new fuel sample and acceptance criteria that must be met prior to adding the new fuel to the DG fuel oil storage tanks; b) tests of the sample of new fuel that may be completed after the fuel is added to the DG fuel oil storage tanks; and, c) tests of the fuel oil stored in the DG fuel oil storage tanks. The basis for each of these tests is described below.

The tests of the sample of new fuel and acceptance criteria that must be met prior to adding the new fuel to the DG fuel oil storage tanks are a means of determining that the new fuel oil is of the appropriate grade and has not been contaminated with substances that would have an immediate, detrimental impact on diesel engine combustion. If results from these tests are within acceptable limits, the fuel oil may be added to the storage tanks without concern for contaminating the entire volume of fuel oil in the storage tanks. The tests, limits, and applicable ASTM Standards needed to satisfy Specification 5.5.12 are listed in the administrative program developed to implement Specification 5.5.12.

Failure to meet any of the specified limits is cause for rejecting the new fuel oil, but does not represent a failure to meet the LCO because the fuel oil is not added to the storage tanks.

The tests of the sample of new fuel that may be completed after the fuel is added to the DG fuel oil storage tanks must be completed Within 31 days. The fuel oil is analyzed to establish that the other properties of the fuel oil meet the acceptance criteria of Specification 5.5.12. The 31 day period is acceptable because the fuel oil properties of interest, even if they were not within stated

(continued)

SURVEILLANCE REQUIREMENTS

SR 3.8.3.3 (continued)

limits, would not have an immediate effect on DG operation. Failure to meet the specified acceptance criteria requires entry into Condition E and restoration of the quality of the fuel oil in the DG fuel oil storage tank within the associated Completion Time and explained in the Bases for Condition E. This Surveillance ensures the availability of high quality fuel oil for the DGs.

The periodic tests of the fuel oil stored in the DG fuel oil storage tanks verify that the length of time or conditions of storage has not degraded the fuel in a manner that could impact DG OPERABILITY. Fuel oil degradation during long term storage shows up as an increase in particulate, due mostly to oxidation. The presence of particulate does not mean the fuel oil will not burn properly in a diesel engine. The particulate can cause fouling of filters and fuel oil injection equipment, however, which can cause engine failure. Particulate concentrations must meet the acceptance criteria of Specification 5.5.12. It is acceptable to obtain a field sample for subsequent laboratory testing in lieu of field testing. Each DG fuel oil storage tank must be considered and tested separately.

The Frequency of this test takes into consideration fuel oil degradation trends that indicate that particulate concentration is unlikely to change significantly between Frequency intervals.

SR 3.8.3.4

The IP3 offsite fuel oil reserve is maintained by the operators of IP2, in accordance with formal agreements. The IP3 offsite DG fuel oil reserve is normally stored in the same tanks used to store the IP2 offsite DG fuel oil reserve. Fuel oil properties of new and stored fuel are controlled in accordance with IP2 Technical Specifications and FSAR in order to meet requirements for the Operability of IP2 and IP3 DGs.

(continued)

BASES

SURVEILLANCE REQUIREMENTS

SR 3.8.3.4 (continued)

Required testing of the properties of new and stored fuel in the offsite DG fuel oil reserve is performed by IP2 in accordance with programs established by IP2. IP3 performs periodic verification that fuel oil stored in the offsite DG fuel oil reserve meet the requirements of Specification 5.5.12.

Failure to meet the specified acceptance criteria, whether identified by IP2 or IP3, requires entry into Condition D or E and restoration of the quality of the fuel oil in the offsite DG fuel oil reserve within the associated Completion Time and explained in the Bases for Conditions D and E.

SR 3.8.3.5

This Surveillance ensures that, without the aid of the refill compressor, sufficient air start capacity for each DG is available. The system design requirements provide for a minimum of ~~four~~ ***three*** engine starts without recharging. Failure of the engine to start within approximately 15 seconds indicates a malfunction at which point the overcrank relays terminate the start cycle. In this condition, ~~sufficient~~ starting air will ~~still~~ be ***un***available so that the DG can***not*** be manually started. The ***entry*** pressure specified in this SR is intended to reflect the lowest value at which the ~~four~~ ***three*** starts can be accomplished.

The 31 day Frequency takes into account the capacity, capability, redundancy, and diversity of the AC sources and other indications available in the control room, including alarms, to alert the operator to below normal air start pressure.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.8.3.6

Microbiological fouling is a major cause of fuel oil degradation.There are numerous bacteria that can grow in fuel oil and cause fouling, but all must have a water environment in order to survive. Removal of water from the fuel storage tanks once every 92 days eliminates the necessary environment for bacterial survival. This is the most effective means of controlling microbiological fouling. In addition, it eliminates the potential for water entrainment in the fuel oil during DG operation. Water may come from any of several sources, including condensation, ground water, rain water, and contaminated fuel oil, and from breakdown of the fuel oil by bacteria. Frequent checking for and removal of accumulated water minimizes fouling and provides data regarding the watertight integrity of the fuel oil system. The Surveillance Frequencies are consistent with Regulatory Guide 1.137 (Ref. 2). This SR is for preventive maintenance. Unless the volume of water is sufficient that it could impact DG OPERABILITY, presence of water does not necessarily represent failure of this SR, provided the accumulated water is removed within 7 days of performance of the Surveillance.

REFERENCES

1. FSAR, Section 8.2.
2. Regulatory Guide 1.137.
3. FSAR, Chapter 14.

The Authority submitted to the NRC its response to the SBO rule. The NRC responded by issuing a Safety Evaluation dated December 23, 1991 and a Supplemental Safety Evaluation dated June 8, 1992. Based on these safety evaluations, and IPN-94-127, dated October 13, 1994, the following SBO-related items are resolved:

7) Habitability of the areas from which the AFW flow control valves and steam generator PORVs are operated during the first hour after the onset of an SBO event was evaluated and determined acceptable.

8) In order to address the effects of loss of ventilation of the control room, control room cabinet doors will be opened within 30 minutes of the onset of an SBO event.

9) The containment Isolation Valve design and operation meets the intent of the guidance described in Regulatory Guide 1.155. Specific containment isolation valves which cannot be excluded based on the 5 criteria given in Regulatory Guide 1.155 are documented to justify their exclusion and ensure that containment integrity will be maintained during an SBO event.

10) All equipment required for response to an SBO shall be classified (at least) Category M, and included in the QA Program.

11) The EDG reliability program follows the guidance and meets the intent of Regulatory Guide 1.155. This program includes monitoring of EDG reliability, surveillance and testing of the EDGs, maintenance program, an information and data collection system and management oversight.

12) The coping duration categorization of IP3 has been revised from four to eight hours.

Any two emergency diesel generator units, as a backup to the normal standby AC power supply are capable of sequentially starting and supplying the power requirement of one minimum required set of safeguards equipment. The three units are located in a seismic Class I structure located near the Control Building.

Each emergency diesel is automatically started by two redundant air motors, each unit having a complete ***49*** ~~53~~ cu ft ***(approximate internal volume)*** air storage tank and compressor system powered from a 480 volt motor. The piping and the electrical services are arranged so that manual transfer between units is possible. Each air receiver has sufficient storage for 4 starts. The diesel will consume, however, only enough air for one automatic start during any particular power failure. ~~This is due to~~ ***Additionally,*** the engine control system~~-which~~ is designed to shutdown and lock out any engine which did not start during the initial try.

The emergency units are capable of being started and sequence load begun within 10 seconds after the initial signal. The starting system is completely redundant for each diesel generator. The units have the capability of being fully loaded within 30 seconds after the initial starting signal.

To ensure rapid start the units are equipped with water jacket and lube oil heating and pre-lube pump for circulation of lube oil when the unit is not running. The units are located in heated rooms.

An audible and visual alarm system is located in the main control room and will alarm off-normal conditions of jacket water temperature, lube oil temperature, fuel oil level, and starting air pressure.

The abnormal conditions that can shut down the diesel generator during an accident are:

1) overcranking
2) low oil pressure
3) overspeed

An auto shutdown alarm system provided three alarms in the Control Room; one for each emergency Diesel Generator. The alarm annunciates when a shutdown, lock out, control switch off auto or loss of DC power condition occurs. These alarms, located in the Control Room, will identify the diesel generator that has been tripped or is prevented from starting, because of a lock-out shutdown condition or loss of DC power.

Each emergency diesel generator was designed to start and come up to speed within ten seconds after initiation of the starting signal. Failure of the engine to start within the timing period of the overcrank time indicates a malfunction. The overcrank relays have a setpoint (approximately 15 seconds) ***or greater than 3 normal starts.*** ~~that allows the diesel engine enough time to start and at the same time, does not allow the air tank to deplete itself. Shutdown conserves the starting air supply so that the engine can be subsequently started after the malfunction is corrected.~~ Low oil pressure indicated by two out of three oil pressure switches shuts down the diesel generator, since the engine cannot run without proper lubrication. Shutdown permits corrective action to be taken before the engine is damaged, and the diesel generator can then be returned to normal operation.

An overspeed condition causes improper generator output and therefore the diesel generator should be shut down for corrective action to be taken to restore the generator output to normal.

For operator indication that one or more emergency diesel generators have been disabled for test or maintenance purposes there is an annunciator window labeled "SAFEGUARDS EQUIPMENT LOCKED OPEN." This alarm is initiated on signals from various safeguards components including the diesels. From any one of the three diesels the following signals would actuate the alarm:

1) Main Control Board Generator Breaker Control Switch in pull-out position
2) Local Generator Breaker Control Switch in pull-out position
3) Local Diesel Control Switch in off or manual position.

Fuel oil for the emergency diesel generators is stored in three 7,700 gallon underground storage tanks located on the south side of the Diesel-Generator Building. There is one common truck hose connection and a 4-inch fill line for all three tanks, complete with a four-inch shutoff valve at each tank. The overflow from any tank will cascade into an adjacent tank. Each tank is equipped with a single vertical fuel oil transfer pump that discharges to either a normal or emergency header. Each header independently supplies the day tank at each diesel. An alarm will sound in the control room if the level in any underground storage tank approaches the level equivalent of the minimum total required inventory identified below less the indicating uncertainty. Administrative action will be taken to refill the tank. In addition, there is a low-level pump cutout switch located on each tank to prevent damage to the fuel oil transfer pump. Each tank is also equipped with a sounding connection and a level indicator. Decrease in level in a day tank to approximately 115 gallons (65% full) will cause the transfer pump in the corresponding underground storage tank to start. Once started, the pump will continue to run

Enclosure 1 To NL-09-119

Indian Point Unit 2 Calculation IP-CALC-06-00329, Rev. 1,

"Replacement of EDG Air Start Motors"

ENTERGY NUCLEAR OPERATIONS, INC.
INDIAN POINT NUCLEAR GENERATING UNIT NOS. 2 and 3
DOCKET NOS. 50-247 and 50-286

☐ ANO-1	☐ ANO-2	☐ GGNS	☒ IP-2	☐ IP-3	☐ PLP
☐ JAF	☐ PNPS	☐ RBS	☐ VY	☐ W3	
☐ NP-GGNS-3	☐ NP-RBS-3				

CALCULATION COVER PAGE	**EC# 9485**	**Page 1 of 18**
Design Basis Calc. ☒ YES ☐ NO	☒ CALCULATION	☐ EC Markup
Calculation No: IP-CALC-06-00329		**Revision: 1**
Title: Replacement of EDG Air Start Motors		**Editorial:** ☐ YES ☒ NO

System(s): EDG Starting Air	**Review Org (Department): Design Engineering (Mechanical)**	
Safety Class:	**Component/Equipment/Structure Type/Number:**	
☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	**21EDSAT**	**21EDGRSM**
	22EDSAT	**22EDGRSM**
	23 EDSAT	**23EDGRSM**
Document Type: Calculation		
Keywords (Description/Topical Codes): EDG and Starting Air Tank	**21EDGLSM**	
	22EDGLSM	
	23 EDGLSM	

REVIEWS

[signature] 7/28/09 Anthony E. Galati/Date **Responsible Engineer**	[signature] 8/5/09 Jerry P. Bubniak/Date ☒ **Design Verifier** ☐ **Reviewer** ☐ Comments Attached	[signature] 9/3/09 Valerie Myers/Date **Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET	CALCULATION NO: IP-CALC-06-00329 REVISION: 1

I. EC Markups Incorporated (N/A to NP calculations)

1. DRN-07-00717
2.
3.
4.
5.

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1. IP-CALC-08-00068		0	☒	☐		
2. 9321-F-2261		27	☒	☐		
3. 9321-F-2259		18	☒	☐		
4. 9321-H-2029		50	☒	☐		
5. Unit 2 Tech Spec			☐	☒	Y	CR IP2-2006-07329
6. Unit 2 Tech Spec Bases			☐	☒	Y	CR IP2-2006-07329
7. Unit 2 UFSAR			☐	☒	Y	CR IP2-2006-07329

III. CROSS REFERENCES:

1.
2.
3.
4.
5.

IV. SOFTWARE USED: None

Title:__________ Version/Release:________ Disk/CD No.______

V. DISK/CDS INCLUDED:

Title:__________ Version/Release________ Disk/CD No.______

VI. OTHER CHANGES:

Revision	Record of Revision
0	Initial issue.
1	Incorporate DRN-07-00717. Revise calculation based on latest information concerning internal volume of starting air tank and EDG crank times. Address concerns raised in CRs IP3-2006-04063 and IP2-2006-07329

TABLE OF CONTENTS

Attachments

Attachment 1 – Excerpts from Vendor Manual 2351-1.2, ALCO Instruction Manual, Information regarding Norgren Lubricators – 6 pages
Attachment 2 - Excerpts from Memorandum From R. J. Doyle, regarding EDG Set Points, dated July 26, 1993 – 3 pages
Attachment 3 - GE Locomotive, Canada, Alco Technical Support response regarding Supplement to Query #277, dated November 5, 1992 – 4 pages
Attachment 4 - Excerpts from Cash Acme Bulletin VV&S-3g, Strainers, dated May 3, 1993 – 2 pages
Attachment 5 - Excerpts from Conval Inc Bulletin CC 6-84, Forged Alloy Steel High Pressure High Temperature Clampseal Valves, dated June 1984 – 3 pages
Attachment 6 - E-mail from Bob Calvin, Ross Controls to David Gaiewski, Proto-Power, regarding Ross Model 2671A8903 valves, dated June 30, 2005 – 1 page
Attachment 7 - E-mail from Chuck Silvene, Tyco Valves & Controls to David Gaiewski, Proto-Power, regarding Cash Acme 'B' Series Pressure Regulator Valves, dated June 30, 2005 – 2 page
Attachment 8 - E-mail from Ted Stevenson, Fairbanks Morse to David Gaiewski, Proto-Power, regarding Indian Point Energy Center Unit 2 EDG Starting Air Requirements, dated August 18, 2005 – 2 pages
Attachment 9 - Compressible Flow Manual (selected pages) – 14 pages
Attachment 10 - E-mail dated 6/24/08 from J. Whitney to R. Sergi – 1 page
Attachment 11 – Excel Spreadsheets – 2 pages

Background

The diesel generator starting air system (DA) provides sufficient compressed air to start (crank) the diesel engines. During emergency operation, starting air is supplied from the starting air tank to the air motors, which in turn cranks the engine. There are two air motors per engine, each capable of starting the diesel in the allotted time. The starting air compressor can replenish the air in the starting air tank; however, the starting air compressor is not a safety related component and its function can not be credited in maintaining air tank pressure.

The original air start motors were manufactured by Ingersoll-Rand, series SS660B. Since replacement parts could no longer be obtained for the existing SS660 series air start motor, a newer maintainable model was installed. The manufacturer's replacement for the SS660 model is the SS810 model which provides an increased torque capacity while maintaining similar speeds and air consumption rates.

Purpose

The purpose of this calculation is to determine the number of normal diesel starts available from the starting air tank (Starting Air Tank No. 21, 22, or 23) without the assistance of air from the starting air compressor. The calculation will determine the system pressure drop between the air receiver and the air start motors in order to establish the minimum air receiver pressure required for a normal start.

Revision 1 of this calculation includes information obtained concerning the start (crank) time of the air start motors and the internal volume of the air receivers. The crank time is estimated to be greater than 3 seconds and the internal volume of starting air receiver was determined to be approximately 49 ft^3 and not 53 ft^3. An ambient temperature of 90^0F is also used in this revision of the calculation. This calculation revision is being performed to address concerns raised in CR's IP3-2006-04063 and IP2-2006-07329 dealing with the existing non-conservative Tech Spec values for starting air tank pressures. (Reference 25)

Conclusion

This calculation demonstrates that if the starting air tank pressure alarm is increased to 255 psig, the starting air tank can provide a minimum of two (2) air starts without assistance from the starting air compressors. The pressure in the air receiver after the second start is 193.8 psia.

The minimum pressure in the air receiver tank required to deliver 880 scfm of air at 90 psig to the inlet of the air start motors is 215 psig.

Input & Design Criteria

1. The firing speed for the diesel is 100 rpm. To attain this, the pinion speed of the starter motor must be 1193 rpm. This requires 880 scfm of air (conservatively based on an inlet pressure of 150 psig). Reference 11.
2. A minimum pressure of 90 psig at the air motor is required for reliable starts, Reference 2.
3. The present internal volume of the starting air tank is 49.3 ft^3 per calculation IP-CALC-08-00068 (Reference 22). A conservative internal volume of 49 ft^3 will be used for this calculation.
4. Piping arrangements for the starting air system are shown on References 8 and 9.
5. The starting air tank is normally maintained at a minimum pressure of 275 psig. The existing starting air tank pressure alarm is set at 250 psig, which is a minimum of 25 psi lower than the normal tank pressure range maintained by the stating air system compressors, Reference 10. An initial starting air tank pressure of 250 psig will be used in this calculation.
6. Room and tank ambient air temperature of 90^0 F will be used for this calculation.

Assumptions

1. Based on information provided in Reference 23 which states that the average crank time for an EDG air start motor is 3 to 3.5 seconds, a conservative average crank time of 4 seconds will be used in this calculation.

2. The starting air system provides compressed air to the ventilation pneumatic control panel which operates the DGB-HVAC pneumatic louvers and dampers. A 30 gallon air receiver provides air to the control panel. The air receiver is supplied by two of the three starting air tanks. These receivers are assumed to be charged.

3. The starting air system provides compressed air to the EDG lubricators. In accordance with Reference 6, these lubricators require an average of 40 SCFM to obtain the maximum drip rate prescribed by the lubricator vendor. Each lubricator is supplied with air from each starting air header that is associated with the EDG. Therefore, this analysis will assume that the air flow through each header will be that required by the air start motor plus 20 SCFM for the lubricator.

Method of Analysis

All equations for this analysis with respect to air flow are from the Compressible Flow Manual, Reference 1.

This calculation will use the manufacturer's air motor consumption data and an average crank time of four (4) seconds to determine the number of air starts available from the start air tank. This calculation will also determine pressure drop from the starting air tank to the air motor. This pressure drop will be used to determine the minimum starting air tank pressure required to ensure a minimum 90 psig can be supplied to the air start motor during the entire 4 second start.

Calculation/Analysis

From Reference 10, the minimum air pressure in the starting air tanks is maintained at 275 psig (290 psia). However, the current alarm set point is 250 psig (265 psia) per Reference 10. A starting air pressure of 250 psig (265 psia) will be used for this calculation. At this pressure, the mass of air in each starting air tank is calculated as follows:

$$m = \frac{144pV}{RT}$$

Where:

m = mass (lbm)
p = pressure (psia)
V = volume (ft^3)
R = Specific gas constant for air (53.35 ft-lbf/lbm °R)
T = Temperature (°R)

Using room temperature for air (90°F or 550°R) and a pressure of 250 psig (265 psia), the initial mass of air in the starting air tank is:

$$m = \frac{144pV}{RT} = \frac{144(265)(49)}{(53.35)(550)} = 63.7\ lbm$$

Based on Reference 11, the firing speed for the diesel is 100 rpm. To attain this, the pinion speed of the starter motor must be 1193 rpm. This requires 880 SCFM of air (conservatively based on an inlet pressure of 150 psig). This flow rate plus the lubricator air supply flow rate will be used to determine the mass of air remaining in the tank after consecutive start attempts.

Based on Reference 23, an average crank time of 4 seconds will be assumed. Therefore, the mass of air evacuated during this period is as follows:

$$\dot{m} = 0.06787\frac{(SCFM)}{R}$$

Where:

$\dot{m}$ = mass flow rate (lbm/sec)
SCFM = Flow rate in standard cubic feet per minute (14.7 psia and 60°F)
R = Specific gas constant for air (53.35 ft-lbf/lbm °R)

Using flow rate of 2 x 880 SCFM + 40 SCFM = 1800 scfm (required flow for both air starters and lubricator), the mass flow from each starting air tank is:

$$\dot{m} = 0.06787\frac{(SCFM)}{R} = 0.06787\frac{(1800)}{53.35} = 2.29\ \text{lbm / sec}$$

Therefore, the amount of air removed from the starting air tank after some time, t, will be:

$$m_{final} = m_{initial} - \dot{m}t$$

After 1 start (4 seconds), the mass in the starting air tank will be:

$$m_{final} = m_{initial} - \dot{m}t = 63.7 - 2.29(4) = 54.54\ lbm$$

The pressure in the starting air tank after 1 start will be:

$$p = \frac{mRT}{144V} = \frac{54.54(53.35)(550)}{144(49)} = 226.8\ psia$$

Tank Pressure change = 265 psia – 226.8 psia = 38.2 psi

After 2 starts (8 seconds), the mass in the starting air tank will be:

$$m_{final} = m_{initial} - \dot{m}t = 63.7 - 2.29(8) = 45.4\ lbm$$

The pressure in the starting air tank after 2 starts will be:

$$p = \frac{mRT}{144V} = \frac{45.4(53.35)(550)}{144(49)} = 188.8\ psia$$

Tank Pressure change = 226.8 psia – 188.8 psia = 38 psi

In this section of the calculation the pressure drop in the piping system between the starting air tank and the air start motors at a flow rate of 900 scfm will be calculated. Based on Starting Air Flow Diagram (Ref 7), the lubricators are supplied from the air header upstream of the air start motors. Therefore a flow rate of 900 scfm (880 + 20) will be used to determine the piping system pressure drop.
The starting air tank pressure after two starts is 188.8 psia. Since the pressure drop in the piping system varies with pressure and increases as pressure decrease, the pressure at the end of the second start will be used to determine the piping system pressure drop.

Pressure drop from starting air tank to pressure control valve

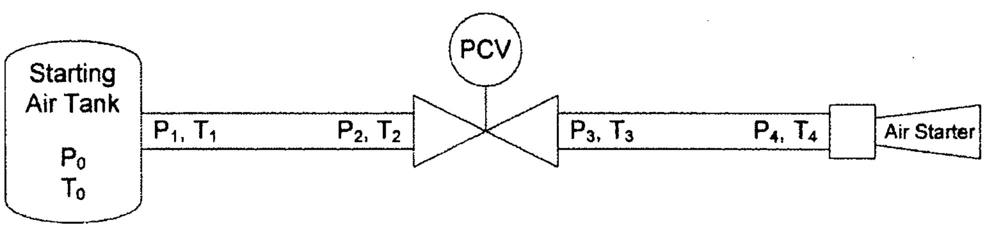
Air pressure to each starting motor is regulated by a pressure control valve (PCV-5003 through PCV-5008). From Reference 10, these reducing valves regulate downstream pressure to 150 ± 15 psig.

Piping from the starting air tank to these valves is depicted on References 8 and 9. As shown on Reference 7, the piping has a nominal pipe size of 1-1/2 inches. From Reference 12, piping is Schedule 40s TP-316 stainless steel.

After a review of all six piping runs, the following represents the most conservative configuration from a hydraulic resistance standpoint. Unless otherwise noted, fitting resistances are based on Reference 13:

Turbulent Friction Factor			
f_t	0.02018	($Re = \infty$, $\varepsilon = 0.00015$)	Colebrook Equation
Piping			
L (ft)	35		
d (in)	1.61		
Pipe K	**5.26**	$= f_t * 12\ L / d$	
Fittings			
1 x Entrance, Sharp Edged, Flush (K = 0.5)	0.5		
9x Std Elbow, 90° ($K = 30f_t$)	5.45	$= QTY * 30 * f_t$	
1x Sudden Enlargement ($d_2 = 2.067$)	0.15	$= (1 - (d_1/d_2)^2)^2$	
1x Sudden Contraction ($d_2 = 2.067$)	0.20	$= 0.5 * (1 - (d_1/d_2)^2)$	
1 x Strainer (Cv = 65)	1.42	$=890\ d^4 / C_v^2$	Reference 14 Cash Acme Strainer
Total Fitting K	**7.72**		
Valves			
1 x Stop Valves (Cv = 38)	4.14	$=890\ d^4 / C_v^2$	Reference 15 CONVAL 11G2J 1.5 Globe valve
Total Valve K	**4.14**		
K Total	**17.12**		

Based on this hydraulic resistance, the pressure drop from the starting air tank to the pressure control valve is as follows:



In the tank, total properties equal static properties ($P_{t0} = P_{s0}$, $T_{t0} = T_{s0}$). Flow from the tank to the piping is taken as isentropic. Therefore, the total properties are constant:

$P_{t0} = P_{t1} =$ **188.8 psia**
$T_{t0} = T_{t1} =$ **550 °R**

The Mach Number at station 1 (M_1) is found as follows:

$$M\left[1+\frac{k-1}{2}M^2\right]^{\frac{k+1}{2(k-1)}} = 0.2245\frac{\dot{m}}{d^2P_t}\sqrt{\frac{RT_t}{k}}$$

Where:

M = Mach number (dimensionless)
k = Isentropic Exponent for air (1.4)
$\dot{m}$ = mass flow rate (lbm/sec)
d = inside pipe diameter (in)
P_t = Total Pressure (psia)
T_t = Total Temperature (°R)
R = Specific gas constant for air (53.35 ft-lbf/lbm °R)

Based on a volumetric flow rate of 900 SCFM, the mass flow rate is:

$$\dot{m} = 0.06787\frac{(SCFM)}{R} = 0.06787\frac{(900)}{53.35} = 1.145 \text{ lbm/sec}$$

Assuming a Mach number of 0.0763 yields the following:

$$M\left[1+\frac{k-1}{2}M^2\right]^{\frac{k+1}{2(k-1)}} = 0.2245\frac{\dot{m}}{d^2P_t}\sqrt{\frac{RT_t}{k}}$$

$$0.0763\left[1+\frac{1.4-1}{2}0.0763^2\right]^{\frac{1.4+1}{2(1.4-1)}} = 0.2245\frac{1.145}{1.61^2(188.8)}\sqrt{\frac{53.35(550)}{1.4}}$$

$$0.0763 = 0.0763$$

Therefore the assumption for M_1 of 0.0763 is correct.

The Mach number at station 2 (M_2) is found as follows:

$$K = \frac{1}{kM_1^2} - \frac{1}{kM_2^2} + \frac{k+1}{2k}\ln\frac{M_1^2\left[2+(k-1)M_2^2\right]}{M_2^2\left[2+(k-1)M_1^2\right]}$$

Where:

K = Loss Coefficient (dimensionless)

Assuming a Mach number at station 2 of 0.0823 yields the following:

$$17.12 = \frac{1}{1.4(0.0763)^2} - \frac{1}{1.4(0.0823)^2} + \frac{1.4+1}{2(1.4)}\ln\frac{(0.0763)^2\left[2+(1.4-1)(0.0823)^2\right]}{(0.0823)^2\left[2+(1.4-1)(0.0763)^2\right]}$$

$$17.12 = 17.12$$

Therefore the assumption for M_2 of 0.0823 is correct. With these Mach Numbers, static pressures at stations 1 and 2 can be found:

$$\frac{P_t}{P_s} = \left[1+\frac{k-1}{2}M^2\right]^{\frac{k}{k-1}}$$

Therefore P_{s1} is:

$$P_{s1} = P_{t1}\Big/\left[1+\frac{k-1}{2}M^2\right]^{\frac{k}{k-1}} = 188.8\Big/\left[1+\frac{1.4-1}{2}(0.0763)^2\right]^{\frac{1.4}{1.4-1}} = 188\ psia$$

And P_{s2} is found as follows:

$$\frac{P_{s2}}{P_{s1}} = \frac{M_1}{M_2}\sqrt{\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}}$$

$$P_{s2} = P_{s1}\frac{M_1}{M_2}\sqrt{\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}} = 188\frac{0.0763}{0.0823}\sqrt{\frac{2+(1.4-1)0.0763^2}{2+(1.4-1)0.0823^2}} = 174.3\ psia = 159.3\ psig$$

Pressure drop across pressure control valve

As shown below, the downstream pressure is less than the valve set pressure minus the set tolerance. Therefore the valve would be full open. From Reference 16, the full open flow coefficient of this valve is 10.6.

Turbulent Friction Factor			
f_t	0.02018	(Re = ∞, ε = 0.00015)	Colebrook Equation
Piping			
L (ft)	0		
d (in)	1.61		
Pipe K	**0.00**	$=f_t * 12\,L / d$	
Valves			
1 x Pressure Control Valve (Cv = 10.6)	53.22	$=890\,d^4 / C_v^2$	Reference 16 Cash Acme 'B' Series Pressure Regulator Valve
Valve K	**53.22**		
K Total	**53.22**		

The Mach number at station 3 (M_3) is found as follows:

$$K = \frac{1}{kM_2^2} - \frac{1}{kM_3^2} + \frac{k+1}{2k}\ln\frac{M_2^2\left[2+(k-1)M_3^2\right]}{M_3^2\left[2+(k-1)M_2^2\right]}$$

Where:
K = Loss Coefficient (dimensionless)

Assuming a Mach number at station 3 of 0.1177 yields the following:

$$53.22 = \frac{1}{1.4(0.0823)^2} - \frac{1}{1.4(0.1177)^2} + \frac{1.4+1}{2(1.4)}\ln\frac{(0.0823)^2\left[2+(1.4-1)(0.1177)^2\right]}{(0.1177)^2\left[2+(1.4-1)(0.0823)^2\right]}$$

$$53.22 = 53.22$$

Therefore the assumption for M_2 of 0.1177 is correct. With these Mach Numbers, static pressure at station 3, P_{s3}, can be found as follows:

$$\frac{P_{s3}}{P_{s2}} = \frac{M_2}{M_3}\sqrt{\frac{2+(k-1)M_2^2}{2+(k-1)M_3^2}}$$

$$P_{s3} = P_{s2}\frac{M_2}{M_3}\sqrt{\frac{2+(k-1)M_2^2}{2+(k-1)M_3^2}} = 174.3\frac{0.0823}{0.1177}\sqrt{\frac{2+(1.4-1)0.0823^2}{2+(1.4-1)0.1177^2}} = 121.8\ psia = 106.8\,psig$$

Pressure drop from pressure control valve to air motor

Piping from the pressure control valve to the air motor is depicted on References 8 and 9. As shown on Reference 7, the piping has a nominal pipe size of 1-1/2 inches. From Reference 12, piping is Schedule 40s TP-316 stainless steel.

A review of all the six piping runs, the following represents the most conservative configuration from a hydraulic resistance standpoint. Unless otherwise noted, fitting resistances are based on Reference 13:

Turbulent Friction Factor			
f_t	0.02018	($Re = \infty$, $\varepsilon = 0.00015$)	Colebrook Equation
Piping			
L (ft)	15		
d (in)	1.61		
Pipe K	**2.26**	$=f_t * 12 L / d$	
Fittings			
4x Standard Elbow, 90° ($K = 30f_t$)	2.42	=QTY * 30 * f_t	
2x Standard Elbow, 45° ($K = 16f_t$)	0.65	=QTY * 16 * f_t	
Fitting K	**3.07**		
Valves			
1 x Solenoid Valve ($C_v = 29$)	7.11	$=890\ d^4 / C_v^2$	References 17 & 21 Ross Model 2771B8011 valve
1 x Stop Valves ($C_v = 38$)	4.14	$=890\ d^4 / C_v^2$	Reference 15 CONVAL 11G2J 1.5 Globe valve
Valve K	**11.25**		
K Total	**16.58**		

The Mach Number at station 4 (M_4) is found as follows:

$$K = \frac{1}{kM_3^2} - \frac{1}{kM_4^2} + \frac{k+1}{2k}\ln\frac{M_3^2\left[2+(k-1)M_4^2\right]}{M_4^2\left[2+(k-1)M_3^2\right]}$$

Assuming a Mach Number at station 4 of 0.1435 yields the following:

$$16.58 = \frac{1}{1.4(0.1177)^2} - \frac{1}{1.4(0.1435)^2} + \frac{1.4+1}{2(1.4)}\ln\frac{(0.1177)^2\left[2+(1.4-1)(0.1435)^2\right]}{(0.1435)^2\left[2+(1.4-1)(0.1177)^2\right]}$$

$$16.58 = 16.58$$

Therefore the assumption for M_4 of 0.1435 is correct. With these Mach Numbers, static pressures at station 4 can be found:

$$\frac{P_t}{P_s} = \left[1 + \frac{k-1}{2} M^2\right]^{\frac{k}{k-1}}$$

And P_{s4} is found as follows:

$$\frac{P_{s4}}{P_{s3}} = \frac{M_3}{M_4}\sqrt{\frac{2+(k-1)M_3^2}{2+(k-1)M_4^2}}$$

$$P_{s4} = P_{s3}\frac{M_3}{M_4}\sqrt{\frac{2+(k-1)M_3^2}{2+(k-1)M_4^2}} = 121.8\frac{0.1177}{0.1435}\sqrt{\frac{2+(1.4-1)0.1177^2}{2+(1.4-1)0.1435^2}} = 99.8\ psia = 84.8\ psig$$

The above calculations demonstrate that at the end of the second start the starting air tank pressure decreases to 188.8 psia and the pressure drop at the design flow rate of 900 scfm will not maintain the pressure at the air motor inlet above 90 psig. See Attachment 11.

To ensure that the pressure at the air motor inlet is above 90 psig, the starting air tank pressure at the end of the second start must be greater than 191.6 psia. See Attachment 11.

To ensure a minimum of two air starts, and to be consistent with Unit 3, the alarm set point should be increased by 5 psi. This will ensure that the pressure at the end of the second start is above 191.6 psia and the air start motor inlet pressure does not drop below 90 psig during a 4 second start.

Since each start depletes the starting air tank pressure by approximately 38.2 psi, the minimum starting air tank pressure in the starting air tank is equal to 191.6 + 38.2 or 229.8 psia or approximately 215 psig.

REFERENCES

1 Bailey M. Coulter, Jr., Compressible Flow Manual, Fluid Research Publishing, 1984

2 GE Canada Response to NYPA Questions, Paragraph 7, dated April 1991

3 Design Drawing D253797-04, EDG Starting Air to Diesel Gen. #21 Loop No.: 1159

4 Design Drawing D253798-03, EDG Starting Air to Diesel Gen. #22 Loop No.: 1160

5 Design Drawing D253799-03, EDG Starting Air to Diesel Gen. #23 Loop No.: 1161

6 Manual Number 2351, Instruction Manual for ALCO (Standby Engines), 6/89

7 Design Drawing 9321-H-2029, Flow Diagram, Starting Air to Diesel Generators

8 Design Drawing 9321-F-2259, Diesel Generator Building, Fuel Oil, Starting Air & Jacket Water Piping, Sheet 2

9 Design Drawing 9321-F-2261, Diesel Generator Building, Fuel Oil, Starting Air & Jacket Water Piping, Sheet 4

10 Memorandum from R. J. Doyle, regarding EDG Set Points, dated July 26, 1993.

11 GE Locomotive, Canada, Alco Technical Support response regarding Supplement to Query #277, dated November 5, 1992

12 Specification No. 9321-01-248-18, Specification for Fabrication of Piping Systems Turbine Generator Plant.

13 Crane Technical Paper No. 410, Flow of Fluids Through Valves, Fittings and Pipe

14 Cash Acme Bulletin VV&S-3g, Strainers, dated May 3, 1993

15 Conval Inc. Bulletin CC 6-84, Forged Alloy Steel High Pressure High Temperature Clampseal Valves, page 8, dated June 1984

16 E-mail from Chuck Silvene, Tyco Valves & Controls to David Gaiewski, Proto-Power, regarding Cash Acme 'B' Series Pressure Regulator Valves, dated June 30, 2005.

17 E-mail from Bob Calvin, Ross Controls to David Gaiewski, Proto-Power, regarding Ross Model 2671A8903 valves, dated June 30, 2005

18 Vendor Drawing TPD869, Performance of SS660B Starters

19 Vendor Drawing TPD660, Performance of SS810 and SS815 Starters

20 E-mail from Ted Stevenson, Fairbanks Morse to David Gaiewski, Proto-Power, regarding Indian Point Energy Center Unit 2 EDG Starting Air Requirements, dated August 18, 2005

21 E-mail from George Hogg to Michael Radvansky regarding the model of the installed SOVs in the IP2 EDG Starting Air System and EDG Fuel Oil Transfer Pump field information, dated January 19, 2007 (attached)

22 IP-CALC-08-00068, Rev. 0, Emergency Diesel Generator Starting Air Tank Internal Volume

23 E-mail dated 6/24/08 from J. Whitney to R. Sergi

24 IP-CALC-07-00021, Rev. 0, Emergency Diesel Generator Starting Air System (IP3)

25 CRs IP2-2006-07329 and IP3-2006-04063

CON EDISON
INDIAN POINT STATION
SYSTEM ENGINEERING

ATTACHMENT 7.2
Page 1 of 1

2351-
NRMC INDEX NO.

VENDOR MANUAL RECORD OF REVISION FORM

MANUAL TITLE: ALCO Instruction Manual

MANUAL NO.: VM-2351

REVISION NO.	REVISION DATE	DESCRIPTION	REVIEW DATE	INITIAL
REV 1-1 ← NEW REVISION SERIES (R1)	1/25/02	SET POINT CHANGES	1/25/02	MCK

CONTROLLED COPY
NO. 12

NORGREN

		To (FAX Number):	9147374318
Sender:	JOHN DOLAN	Recipient:	ERNIE LEANDER
Date/Time:	11/19/90	Company:	Con ED
FAX Transmittal No.:		Page	1 of 2
Subject:	10-006-015 LUBRICATOR		

063-01
ge 4 of 23

IP-CALC-06-00329 Rev. 1
Attachment 1
Page 2 of 6

NORGREN • 5400 S. Delaware • Littleton, CO 80120 • (303) 794-2611
FAX Numbers: (303) 798-4856 — Customer Service • (303) 795-9487 — All Other Departments

NORGREN

November 19, 1990

Mr. Ernest Leander
Planning Specialist
Consolidated Edison
Indian Point Station
Broadway and Beakley Ave.
Buchanan, NY 10511

Dear Ernest:

Subject: Replacement of 10-006-015 Lubricator

I am writing in response to your request for information on the replacement of our 10-006-015 lubricator. I understand that your application involves lubrication of an air motor start up system. For this application, our current part L12-200-MPLA would be the replacement for the obsolete 10-006-015. There are other applications where another lubricator would be the replacement.

Please feel free to contact me if you have additional questions.

Regards,

NORGREN CO.

John Dolan
Service Engineer

JD/mcs
cc: Rick Cavalere
The Knotts Company

IP-CALC-06-00329 Rev. 1
Attachment 1
Page 3 of 6

INSTALLATION

1. *Air line piping should be same size as lubricator ports.*
2. Install lubricator vertically (adjustment knob up) in air line downstream of filter and regulator as near as possible to device being served. This type of lubricator should not be installed downstream of frequently cycling directional control valves. Special rapid-cycle (bi-directional) oil-fog lubricators or multi-point injection lubricators are available for use under such conditions.
3. *Connect piping to proper ports using pipe thread sealant on male threads only.* Do not allow sealant to enter interior of lubricator.
4. Fill lubricator with a good quality lubricant (see Specifications) to level indicated by maximum fill line or, if equipped with sight glass, oil should always be visible in glass. DO NOT OVERFILL.

ADJUSTMENT

1. Turn lubricator drip rate adjusting knob fully clockwise, then turn on system *air pressure.*
2. Adjust lubricator drip rate only when there is a constant rate of air flow thru the lubricator. Monitor drip rate thru sight feed dome.
3. Determine the average rate of air flow (scfm) thru the lubricator, then turn the adjusting knob to obtain the recommended drip rate (Drops/Min). See Drip Rate Charts. Turn adjusting knob counterclockwise to increase and clockwise to decrease the drip rate. Push *lockring on adjusting knob downward to lock drip rate setting. To release, pull lockring upward.*

DRIP RATE CHARTS

L11 & L12 – 1/4" PORTS

Avg. scfm		2	4	6	8	10	12	14	16	18	20
Drops/	L11	5	8	10	12	14	16	18	20	–	–
Min.	L12	2			3			4			5

L11 & L12 – 3/8" PORTS

Avg. scfm		5	10	15	20	25	30	35	40
Drops/	L11	12	21	30	40	50	60	70	80
Min.	L12	3	4	5	6	7	8	9	10

L12 – 1/2" & 3/4" PORTS

Avg. scfm	5	10	20	30	40	50	60	70	80	90	100
Drops/Min.	10	11	13	15	17	19	22	24	26	28	30

L17 – 3/4" PORTS

Avg. scfm	10	20	40	60	80	100	120	140	160
Drops/Min.	8	10	12	14	16	18	20	22	24

L17 – 1", 1-1/4", 1-1/2" PORTS

Avg. scfm	10	25	50	75	100	125	150	175	200	225	250	275
Drops/Min.	10	14	21	28	35	41	47	54	60	66	73	80

4. Monitor the device being lubricated for a few days following initial adjustment. Readjust the drip rate if the oil delivery at the device appears either excessive or low.
5. *Drip rate setting can be made tamper resistant by installing a seal wire* (see Accessories) in groove above lockring.

CLEANING

1. Clean transparent reservoir (19) using warm water only. Clean other *parts using soap and water. Dry parts and blow out internal passages in body (1) using clean, dry compressed air.*
2. Inspect all parts carefully.
3. *Replace damaged parts. If transparent reservoir shows signs of cracking or cloudiness, replace with metal reservoir.*

DISASSEMBLY

1. Shut off inlet pressure and reduce pressure in inlet and outlet lines to zero. Loosen fill plug. Lubricator can be disassembled without removal from air line.
2. On models equipped with polycarbonate reservoir and guard, rotate guard (20) around body (1) to 'wind out' retainer (21) through slot in guard. Slide guard off body.
3. Disassemble in accordance with the appropriate exploded view. Do not remove syphon tube (4) on L11 and L12 models unless replacement is necessary.

REASSEMBLY

1. Lubricate the following items prior to reassembly.

ITEM	LUBRICANT
3, 30, 32	Generous coat of Dow Corning 44 grease (or equivalent).
10, 29, 42, 45 on L12 .... (metal threads)	Small, even amount of Armite™ Laboratories anti-seize compound Led-Plate 250 (or equivalent).

2. Assemble the lubricator as shown in the appropriate exploded view.
3. Tighten the following items to r[illegible]ified torque.

ITEM	[illegible]GUE (INCH-POUNDS)
24, 28	[illegible]
8, 9, 10	[illegible]0 to 35
43	Apply increasing torque in a diagonal pattern. Apply final torque of 20 to 30 inch-pounds in a circular pattern.
33	7 to 10

WARNING

DO NOT OVER TORQUE RETAINER (33) AS DAMAGE TO GAUGE GLASS CAN OCCUR.

4. Assemble the reservoir to the body as described below.

ITEM	PROCEDURE
L11 & L12 – 19, 42, 45	Turn hand tight into body.
L17 – 19, 29A, 34, 48 ...	Turn into body until stop. Arrowhead on reservoir must be to right of arrowhead on body.
L11 & L12 – 29	Tighten approximately 5 turns to stop, then unscrew no more than one full turn to position sight glass for best visibility.

5. If lubricator has a polycarbonate reservoir, reinstall guard (20) on body (1) with retainer bead in guard in line with groove in body. *Insert several inches of retainer (21) into body groove through* slot in guard. Rotate guard around body to 'wind in' retainer.

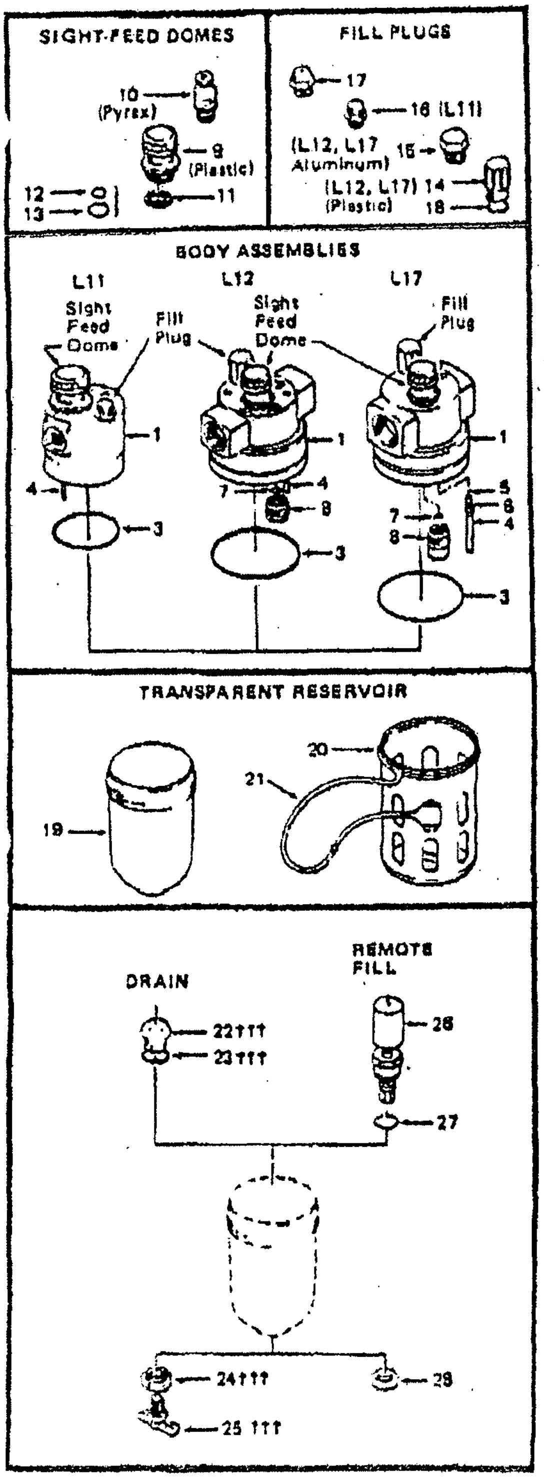
PARTS DESCRIPTION FOR EXPLODED VIEW

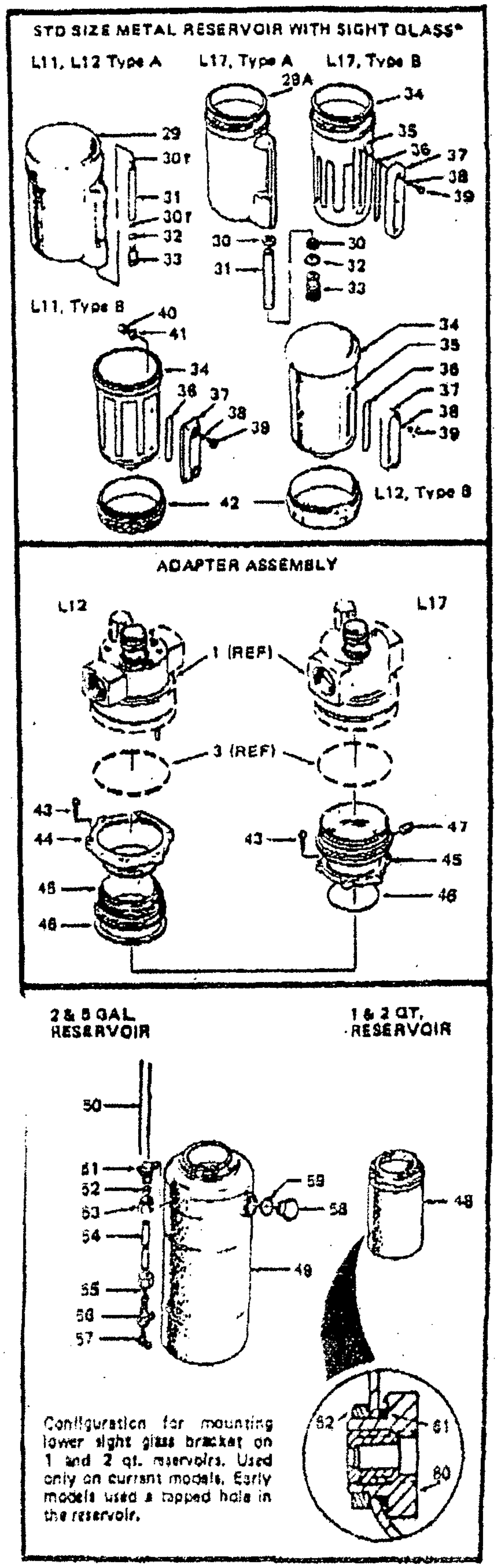
1. Body
3. O-ring
4. Siphon tube
5. Check ball
6. Siphon tube fitting
7. O-ring
8. Fog generator
9. Plastic sight-feed dome
10. Pyrex sight-feed dome
11. Seal
12. O-ring (item 11 alternate)
13. O-ring (item 11 alternate)
14. Plastic fill plug
15. Aluminum fill plug (L12 & L17)
16. Aluminum fill plug (L11)
17. *Quick fill cap (alternate for items 14, 15, 16)*
18. O-ring (gasket on L11)
19. Polycarbonate reservoir
20. Reservoir guard
21. Guard retainer
22. Insert
23. Gasket
24. Nut
25. Drain petcock
26. Remote fill device
27. Gasket
28. Nut
29. L11 & L12 (Type A) std size *metal reservoir with sight glass**

29A. L17 (Type A) std size *metal reservoir with sight glass**

31. Gauge glass
32. *O-ring*
33. Retainer
34. Type B standard size metal reservoir with sight glass (L11, L12, L17)* ††
35. Film
36. O-ring
37. *Gauge glass*
38. O-ring (2 req'd for L11 & L12; 3 req'd for L17)
39. Screw (2 req'd for L11 & L12; 3 req'd for L17)
40. Nut (2 req'd)
41. Plain washer (2 req'd)
42. *Retaining ring*
43. Screw (6 req'd)
44. Clamp ring
45. Adapter
46. Gasket
47. *Pipe plug*
48. Metal rsvr with sight glass (1 & 2 qt. L12, 2 qt. L17)
49. Metal rsvr with sight glass (2 & 5 gal. L12 & L17)
50. Guard (2 req'd)
51. Upper bracket
52. Packing (2 req'd)
53. Packing nut (2 req'd)
54. *Gauge glass*
55. Float ball
56. Lower bracket
57. Drain petcock
58. Fill plug
59. Gasket
60. Insert
61. O-ring
62. Nut

IP-CALC-06-00329 Rev. 1
Attachment 1
Page 4 of 6





Configuration for mounting lower sight glass bracket on 1 and 2 qt. reservoirs. Used only on current models. Early models used a tapped hole in the reservoir.

*Standard sizes are 1/3 pt. (L11), 1/2 pt. (L12), 1 qt. (L17).

†Sight glass seals may be cup shaped or flat. These are not interchangeable. Cup shaped seals must be replaced with cup shaped seals, and flat seals with flat.

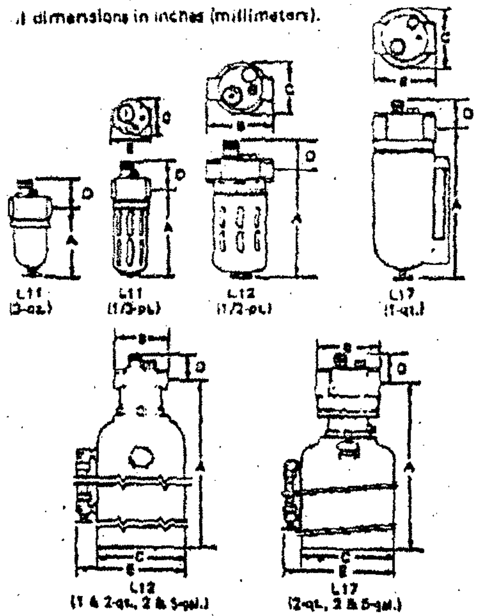
††These bowl assemblies are obsolete and are no longer available. Replaced by item 29 or 29A.

†††Some standard size metal reservoirs have a 1/8" tapped drain hole and use only item 28 (items 22, 23, and 24 not used).

IP-CALC-06-00329 Rev. 1
Attachment 1
Page 5 of 6

..NSIONS

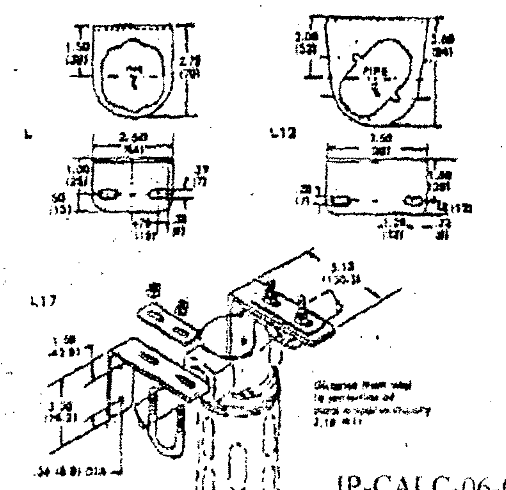
..l dimensions in inches (millimeters).



RSVR SIZE		INCHES (MILLIMETERS)				
		A	B	C DIA.	D	E
L11	3-oz.	4.23 (107)	2.56 (65)	2.31 (59)	Std. Dome: 1.89 (47.0)	–
	1/3-pt.	5.75 (146)		2.47* (63)	Pyrex Dome: 2.51 (64.0)	–
L12	1/2-pt.	6.69 (170)	1/4" & 3/8" Ports: 2.56 (65)	3.14** (80)		–
	1-qt.	9.56 (243)		4.06 (103)	Std. Dome: 1.66 (48.0)	4.94 (125)
	2-qt.	11.81 (300)	1/2" & 3/4" Ports: 3.51 (89)	4.63 (118)		5.38 (137)
	2-gal.	19.38 (506)		6.25 (159)	Pyrex Dome: 2.53 (64.0)	7.44 (189)
	5-gal.	22.88 (581)		10.25 (260)		11.44 (291)
L17	1-qt.	10.34 (260)	4.50 (114)	4.33 (110)	Std. Dome: 2.22 (56.4)	–
	2-qt.	13.13 (333)		4.63 (118)		5.38 (137)
	2-gal.	21.19 (538)		6.25 (159)	Pyrex Dome: 2.72 (69.1)	7.44 (189)
	5-gal.	24.19 (614)		10.25 (260)		11.44 (291)

*2.47 with bowl guard; 2.31 (59) without guard.
**3.14 with bowl guard; 3.01 (76) without guard.

WALL MOUNTING BRACKET



PARTS & ACCESSORIES ILLUSTRATED

	L11	L12	L17
9. Plastic Sight-Feed Dome (Includes item 11)	5055-54	5055-54	5055-54
10. Pyrex Sight-Feed Dome (Includes item 11) (item 15 included with L12 & L17 pyrex dome)	5608-60	5605-60	5605-60
15. Aluminum Fill Plug (Includes item 18)	–	5301-60	5301-50
16. Aluminum Fill Plug (Includes item 18)	1208-60	–	–
17. Quick Fill Cap (Alternate for items 14, 15, 16) (Includes item 18)	18-011-008	18-011-021	18-011-0:
19. Polycarbonate Reservoirs			
3 oz. (closed bottom)	3786-03	–	–
3 oz. (with drain, items 18 and 22 thru 28)	3786-52	–	–
Standard size (closed bottom)	3150-04	5229-58	–
Standard size (with drain, items 18, and 22 thru 25)	3155-55	5229-51	–
Standard size (with remote fill, items 18, 26, 27, 28)	3155-60	5229-60	–
20. Reservoir Guard (Includes item 21) For standard size rsvrs	5176-02	5270-81	–
21. Retainer	5177-87	5177-88	–
29. L11 & L12 Std Size Metal Rsvr With Sight Glass			
With closed bottom (items 29 thru 33)	3200-58	5880-58	–
With drain (items 22 thru 28; 29 thru 33)	3200-60	5880-60	–
With remote fill (items 26 thru 33)	3200-54	5880-54	–
29A. L17 (Type A) Std. Size Metal Rsvr With Sight Glass and Drain (items 22 thru 25; 29A thru 33)	–	–	5390-3
48. Adaptor Gasket	–	1029-01	2841-3
48. 1-Quart Metal Reservoir With Sight Glass (items 48, 50 thru 57, 60, 61, 62)	–	648-20	–
2-Quart Metal Reservoir With Sight Glass (items 48, 50 thru 57, 60, 61, 62)	–	648-28	648-28
49. 2-Gallon Metal Reservoir With Sight Glass (items 49 thru 58)	–	3416-01	3416-0
5-Gallon Metal Reservoir With Sight Glass (items 49 thru 58)	–	3415-01	3415-0
59. Fill Plug Gasket (2 & 5 gal. rsvrs only)	–	1981-01	1981-0
61. O-ring (1 & 2 qt. rsvrs only)	–	2306-14	2306-1

ACCESSORIES NOT ILLUSTRATED

	L11	L12	L17
Tamper Resistant Seal Wire (for plastic sight-feed dome only)	2117-01	2117-01	2117-(
Mounting Bracket			
L11 (1/3 pt.)	5203-02	–	–
L12 (1/2 pt., 1 qt., 2 qt.)	–	5532-04	–
L17 (1 & 2 qt. with 3/4" & 1" ports)	–	–	5212-
L17 (1 & 2 qt. with 1-1/4" & 1-1/2" ports)	–	–	6212-
Mounting Strap (L12 & L17 only)			
2 gal.	–	18-001-058	18-00
5 gal.	–	18-001-039	18-00
Low Oil Level Switch (L12 & L17 only)			
1 qt.	–	18-023-602	–
2 qt.	–	18-023-604	18-0:
2 gal.	–	18-023-606	18-0:
5 gal.	–	18-023-608	18-0:
High/Low Oil Level Switch (L12 & L17 only)			
2 gal.	–	18-023-652	18-0:
5 gal.	–	18-023-654	18-0:

REPAIR KITS

	L11	L12	L17
O-rings (items 3, 7, 11, 18, 23, 27)	5324-01	5771-01	577'
Sight Glass (Type A - L11, L12, L17) (items 30, 31, 32)	2273-13	2273-08	227:
Sight Glass (Type B - L11, L12, L17) (items 35 thru 38)	2273-07	2273-06	227:
Sight Glass (items 50, 52 thru 55)			
L12 (1 qt.)	–	2272-02	
L12 & L17 (2 qt.)	–	2273-04	227
L12 & L17 (2 & 5 gal.)	–	2274-01	227

C. A. NORGREN C
LITTLETON, COLORADO 80120 / 303-79-

IP-CALC-06-00329 Rev. 1
Attachment 1
Page 6 of 6

NIP-380/9-82

Printed in

ConEdison memorandum

Indian Point Station
July 26, 1993

TO: Distribution

FROM: R.J. Doyle
Sr. System Engineer

SUBJECT: EDG Set Points

On May 9, 1989 OIR 89-05-247 was issued to clarify the Emergency Diesel Generator Set Points and operating parameters. These items are not addressed with the Set Point document and were in technical specifications, FSAR, Operating Procedures and Test Procedures. Some are in conflict with others. The answer to this OIR plus ESR's and Modification Procedures are listed in the attached pages.

These are the official Set Points.

R-23

OPERATIONS
McAvoy, J.
Allen, R.
Durr, W.
Griffin, P.

MAINTENANCE
Adinolfi, A.
Nichols, R.
Williams, E.

PLANNING
Mitchell, J.
Leander, E.

INSTRUMENT & CONTROLS
McCann, J.
Harris, R.

SPECIAL PROJECTS
Blatt, M.

PLANT ENGINEERING
Mullin, V.
Kawula, L.
Sutton, R.
O'Toole, W.
Hinshaw, D.

TEST & PERFORMANCE
Hugo, G.
Hughes, G.

TRAINING
Walsh, T.
Inzirillo, F.

NUCLEAR SAFETY & LICENSING
Jackson, C.
Whitney, M.

DBD
Louie, R.

Rev 1-1 (R1-1) changes (pages 5, 9 + 10) eh reflect verified SPIN Database Setpoints.

R1-1

15 pages

DIESEL AIR STARTING SYSTEM

76. ~~75.~~	DIESEL AIR STARTING COMPRESSOR RELIEF VALVES (DA-5, DA-5-1, DA-5-2)	385 PSIG
77. ~~76.~~	AIR RECEIVER TANK RELIEF VALVES (DA-28, DA-28-1,DA-28-2)	#21 325 PSIG +10% -0 #22 330 PSIG +10% -0 #23 335 PSIG +10% -0
78. ~~77.~~	DIESEL AIR STARTING COMPRESSOR START AND STOP CONTROLS (PS-12A, PS-13, PS-14)	275 PSIG START 300 PSIG STOP
79. ~~78.~~	DIESEL AIR STARTING RECEIVER TANK LOW PRESSURE AIR ALARM (PC-1159-S, PC-1160-S, PC-1161-S)	250 PSIG
80 ~~79.~~	AIR REGULATOR FOR VENTILATION LOUVER CONTROL AIR RECEIVER (PRV-5469)	300 PSIG TO 100 PSIG
81 ~~80.~~	VENTILATION LOUVER CONTROL AIR RECEIVER RELIEF VALVE (DA-595)	125 PSIG
82 ~~81.~~	VENTILATION LOUVER CONTROL AIR LINE FROM AIR RECEIVER TANK TO AIR REGULATING VALVE RELIEF VALVE.	100 PSIG TO 15 PSIG
83 ~~82.~~	VENTILATION LOUVER CONTROL AIR LINE FROM AIR RECEIVER TANK TO AIR REGULATOR RELIEF (DA-501)	20 PSIG
84 ~~83.~~	AIR STARTING REDUCING VALVES (PCV-5003 THRU PCV-5008)	300 PSIG TO 150 PSIG + OR - 15 PSIG (ESR # 89-028280)

DIESEL AIR STARTING SYSTEM (CONT'D)

85 ~~84~~.	AIR STARTING RELIEF VALVES (DA-25'S)	175 PSIG
86 ~~85~~.	LOW AIR PRESSURE STARTING ALARMS (PS-9'S, PS-10'S, PS-11'S)	90 PSIG
87 ~~86~~.	MINIMUM AIR PRESSURE IN AIR RECEIVERS TO START AIR IN MANUAL.	275 PSIG
88 ~~87~~.	NORMAL STARTS	EACH AIR RECEIVER HAS ENOUGH AIR FOR AT LEAST 4 NORMAL STARTS.

GE Locomotives Canada

ALCO TECHNICAL SUPPORT
FAX: (514) 253 - 7391

Querie No.:
Group: 18

Contact:	Company:	Date Rec'd:
JOE GRECO	CON-EDISON	92 11 05 (yy mm dd)
Phone:	Fax:	Time:
212-460-2061	212-677-5742	13:00
Operator:	Location/Vessel:	Sales Order:
CONSOLIDATED EDISON	BUCHANAN N.Y.	DE-35211

Model No:	GHP:	RPM:	Unit No:	Serial No:	Book:	TPI:	DRP:
16-251E	2450	900			72	899	907-A

Query Details: SUPPLEMENT TO QUERIE #277.

- THE AIR CONSUMPTION OF SS-810 STARTER MOTOR AS SHOWN ON PERFORMANCE CURVE FAXED TO CON-ED (921030) IS ABOUT 1500 SCFM, ALMOST DOUBLE THAT OF SPECIFIED WITH ORIGINALLY SUPPLIED STARTER MOTORS MODEL 660. CON-ED'S RECORDS SHOW THAT ALCO SIZED THE STARTING SYSTEM FOR A AIR CONSUMPTION OF 800 SCFM @ 150 PSIG FOR ORIGINALLY SUPPLIED STARTER MOTORS MODEL SS-660

THEIR ALCO RECORDS SHOW - 150 PSIG
2600 RPM SPINDLE SPEED (100 RPM ENGINE)
800 SCFM REQUIRED

- IS 1500 SCFM THE CORRECT AIR CONSUMPTION REQUIRED FOR THE SAME OPERATION CONDITION FOR THE SS-810.

Engine Down A	Troubleshooting B	Warranty C	Oper & Maint D	Design/Perf E	Spare Part Inq. F	Nuclear N
				✓		✓

Answer: Date Started: 921109 Time: 14:00

THE PERFORMANCE CURVES FAXED ON 921030 SPECIFY PINION SPEED AS OPPOSED TO SPINDLE SPEED SHOWN ON YOUR ALCO RECORDS. PINION SPEED IS 2.18 THE SPEED OF THE SPINDLE, THEREFORE AT 1193 RPM PINION SPEED THE SPINDLE SPEED IS 2600 RPM.

SEE ATTACHED SS660 PERFORMANCE CURVE ATTACHED

6B05R31

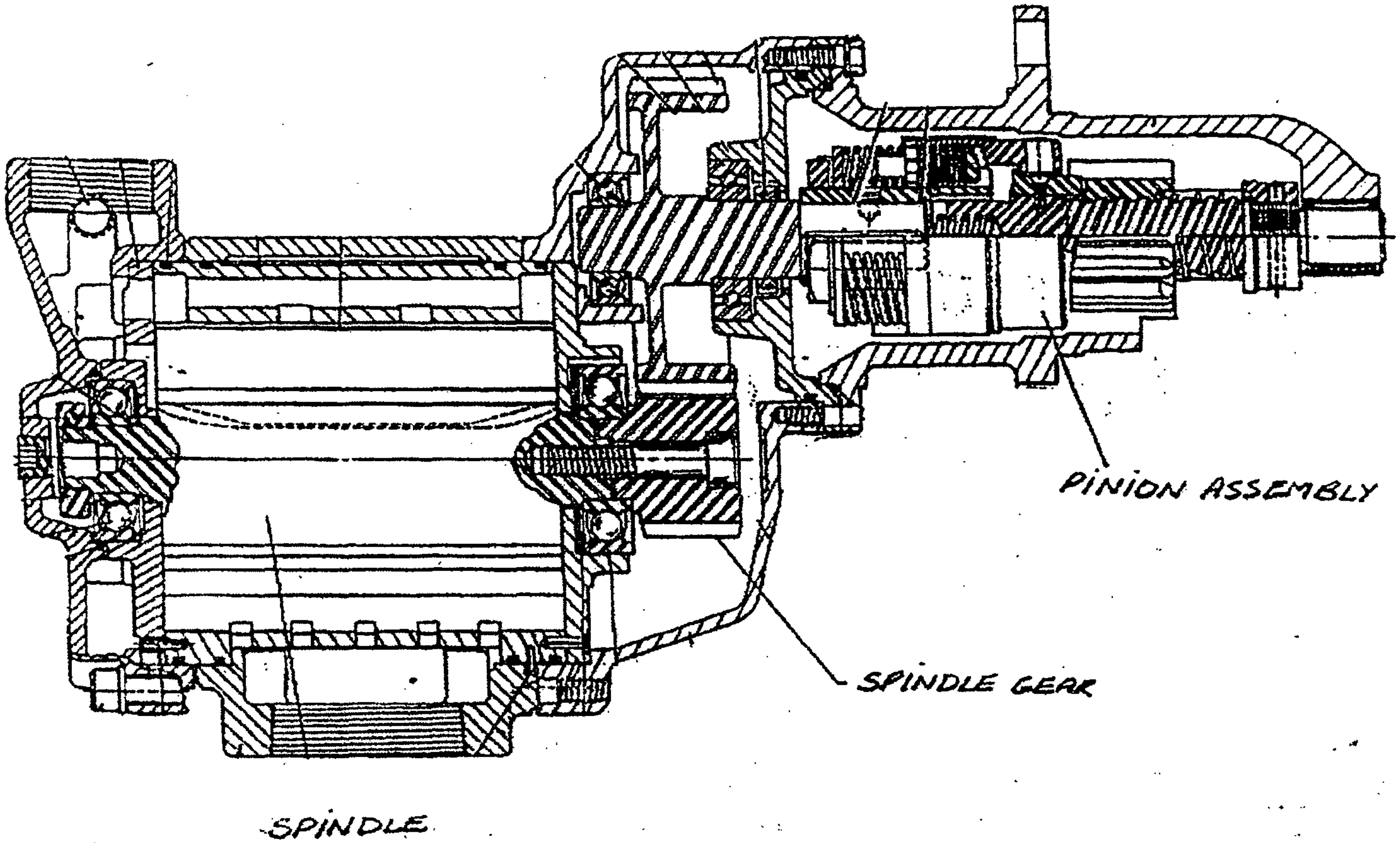
Signed: [signature] Tel: (514)253 2584

Date Sent: 921111
Time: 14:45

IP-CALC-06-00329 Rev. 1
Attachment 3
Page / of 4

(12)

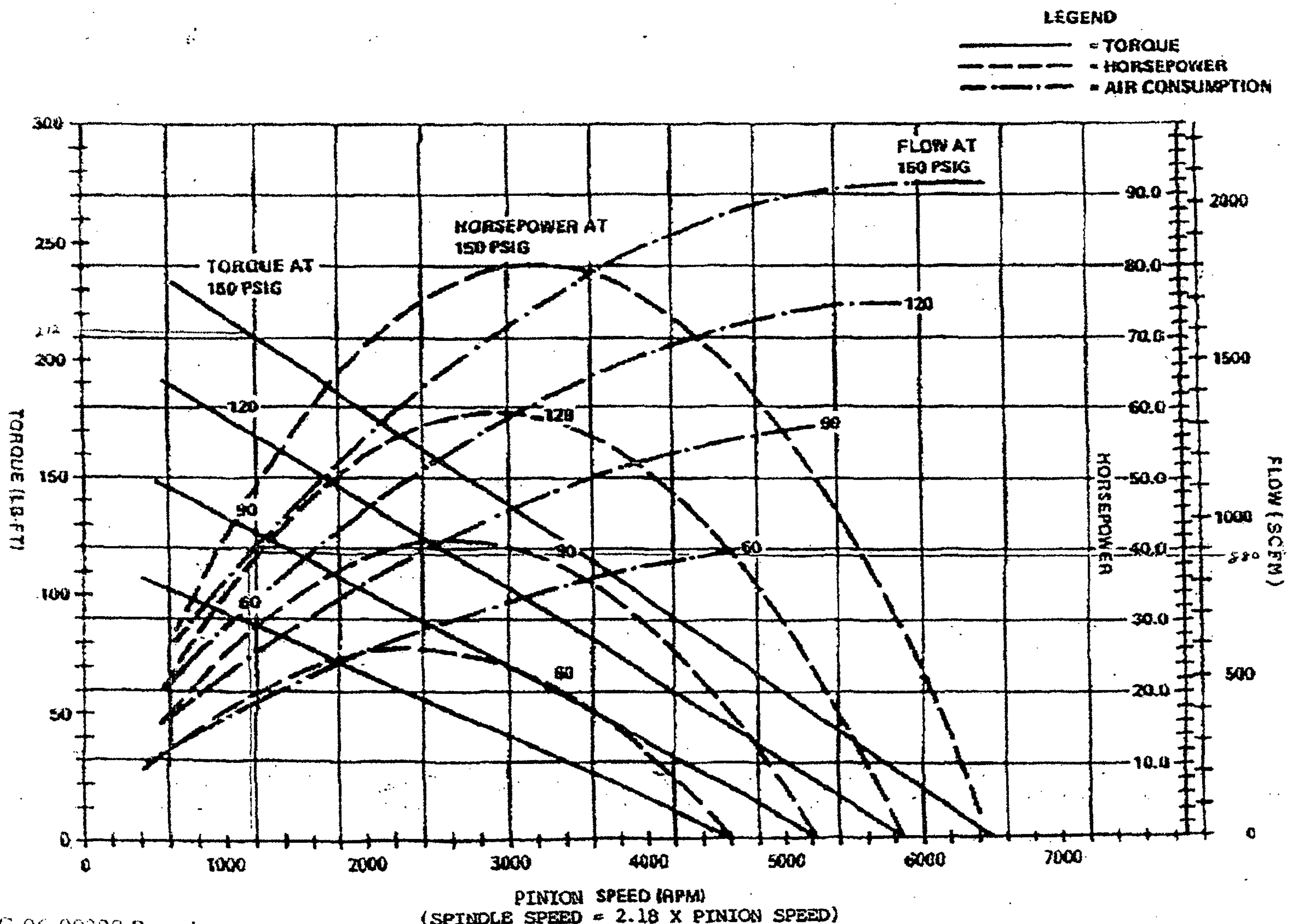
IP-CALC-06-00329 Rev. 1
Attachment 3
Page 2 of 4



(129)

PERFORMANCE OF ' AND SS815 STARTERS

(128)

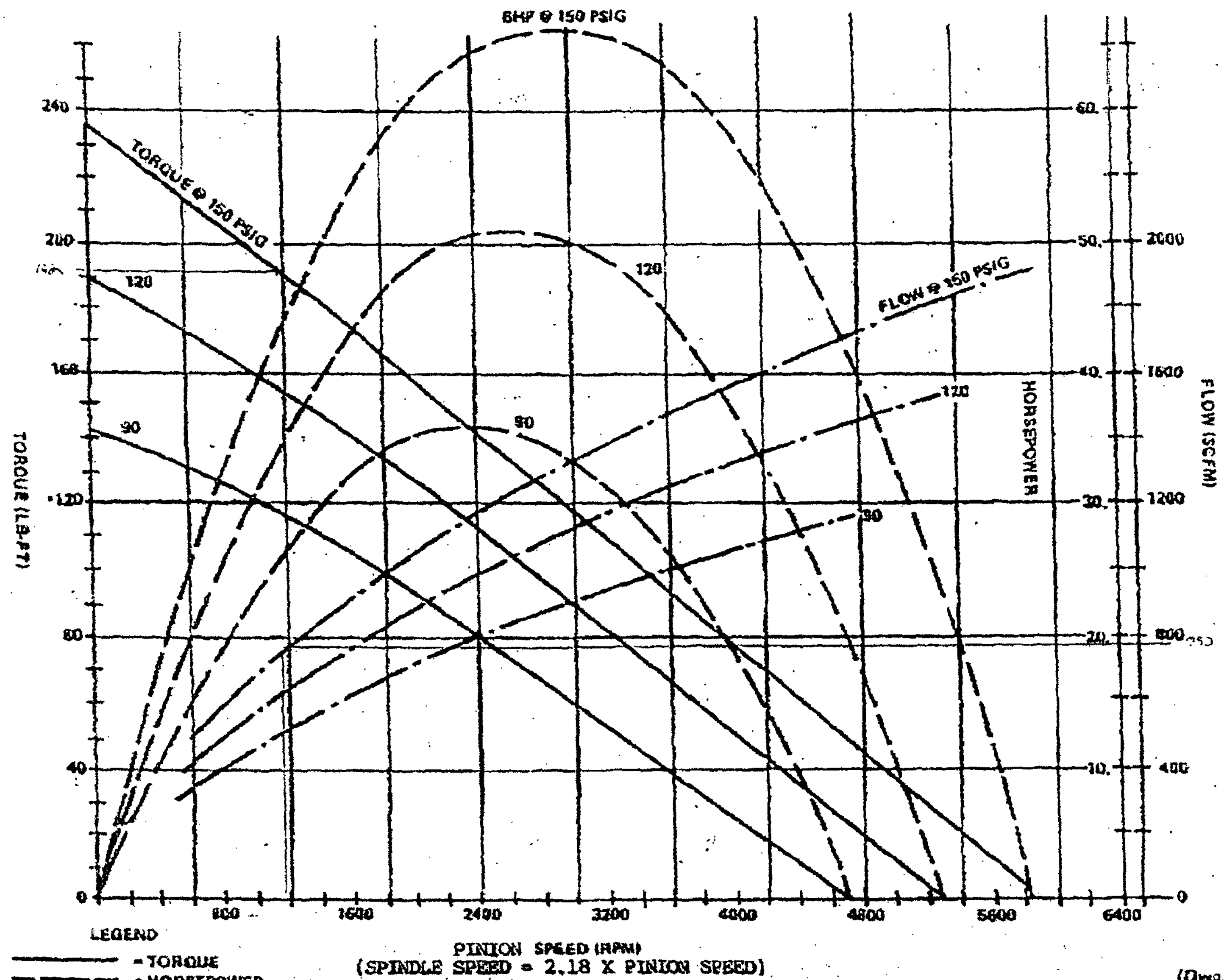


(Dwg. TPD66'

IP-CALC-06-00329 Rev. 1
Attachment 3
Page 3 of 4

IP-CALC-06-00329 Rev. 1
Attachment 3
Page 4 of 4

PERFORMANCE OF SS660B STARTERS

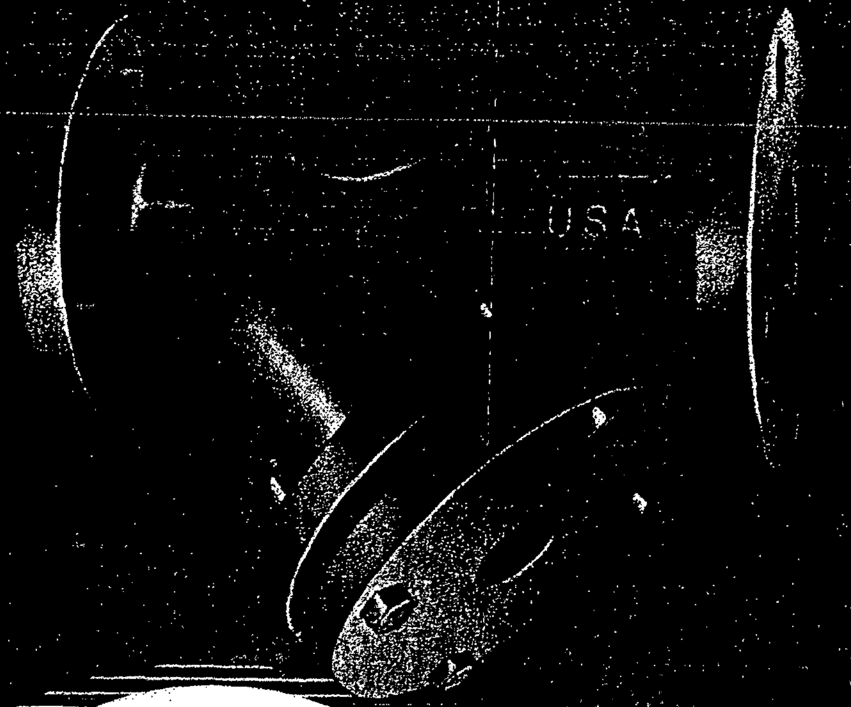


LEGEND
- ——— = TORQUE
- — — — = HORSEPOWER
- —·—·— = AIR CONSUMPTION

(Dwg. TPD869)

127

BULLETIN: VV&S-3g
ISSUED: MAY 3, 1993



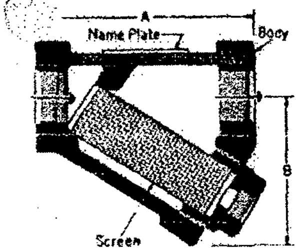
CASH ACME

STRAINERS

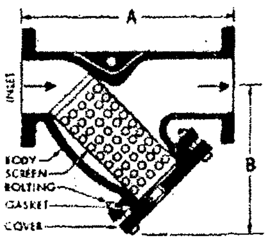
INDEX:

IP-CALC-06-00329 Rev. 1
Attachment 4
Page 1 of 2

"Y" PATTERN STRAINERS
DIMENSIONS AND PRESSURE DROP DATA



TYPE SY-70 INTERIOR
(¼"-2" Screwed)



FLANGES TO STANDARD ASA SPECIFICATIONS

FLANGED TYPE SY-70
INTERIOR

SIZE AND DIMENSION INFORMATION

Size Inches	Body Connection	Body Material	Blowoff Plug Size In. NPT	Screen Area Square Inches	Dimensions (In.) A	Dimensions (In.) B	Shipping Wt. (Lbs.)
				Iron	Iron	Iron	Iron
¼	Screwed	Iron	¼	3.0	2 27/32	1¾	1¼
⅜	Screwed	Iron	¼	3.0	2 27/32	1¾	1¼
½	Screwed	Iron	⅜	5.4	3 5/16	2 11/16	1½
¾	Screwed	Iron	⅜	8.7	4⅜	3¼	2½
1	Screwed	Iron	½	11.9	4⅞	3½	4½
1¼	Screwed	Iron	¾	16.2	5⅞	4¼	6½
1½	Screwed	Iron	¾	23.2	6¾	4 11/16	8¾
2	Screwed	Iron	1	35.0	7½	5 5/8	12½
2	125# flg.	Iron	1	34.5	9⅞	6½	24
2	250# flg.	Iron	1	34.5	11¾	6¾	28
2½	Screwed	Iron	1¼	47.9	9	8¼	22½
2½	125# flg.	Iron	1¼	47.3	10⅞	7	33
2½	250# flg.	Iron	1¼	47.3	13	8¾	38
3	Screwed	Iron	1¼	64.8	10	7¼	35¾
3	125# flg.	Iron	1¼	64.8	12	8	44
3	250# flg.	Iron	1¼	64.8	14	8	54
4	125# flg.	Iron	1¼	127.2	14½	10¾	85
4	250# flg.	Iron	1¼	127.2	17 5/16	10¾	110

STRAINER PRESSURE DROP DATA

Pressure drop tests for data contained on charts based on standard screens ..ed for liquid service. Tests indicate a 25% increase in pressure drop with ..ns 50% clogged. These figures are based on non-reinforced screens.

..W COEFFICIENT: The flow coefficient (Cv) is the number of gallons per minute of water flowing through a given size restriction at a pressure drop of one psi.

CV FACTORS

SIZE	¼&⅜	½	¾	1	1¼	1½	2	2½	3	4
FACTOR	5.0	8.5	18	29	45	65	97	135	185	290

MULTIPLYING FACTORS

To determine pressure drop for liquids other than water please refer to multiplying factor data.

NON-STANDARD SCREENS

STRAINER SIZE	% OPEN AREA		
	35 or Over	25-35	20-35
¼-1	1.0	1.0	1.15
1¼-2	1.0	1.0	1.4
2½-4	1.0	1.2	1.8

SPECIFIC GRAVITY IS OTHER THAN 1:

Multiply the pressure drop from the curves by the specific gravity of the liquid. (Note: when specific gravity is less than 1, use 1 as the factor).

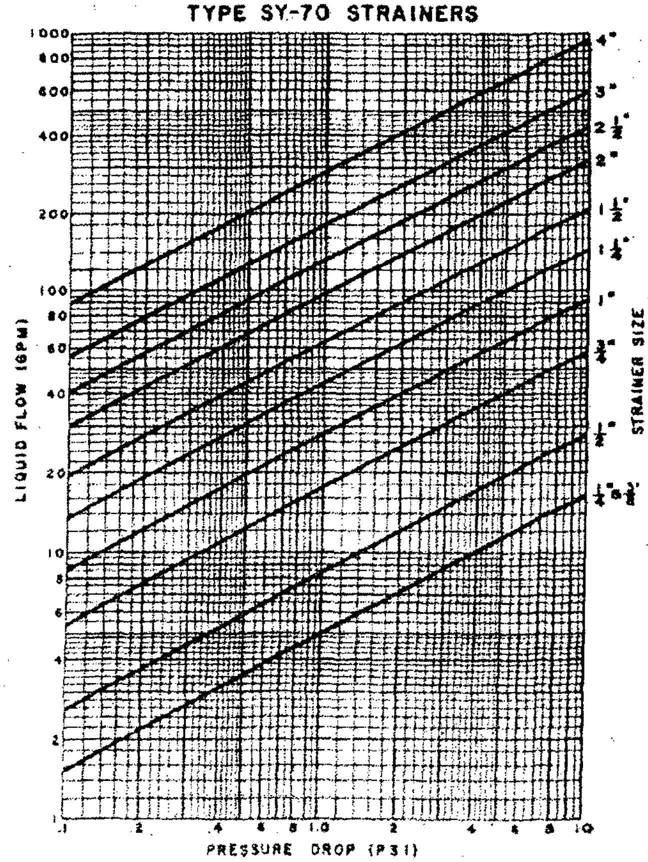
VISCOSITY OTHER THAN 34 SSU:

SSU	Factor	SSU	Factor	SSU	Factor	SSU	Factor
40	.98	100	.70	700	.43	4000	.31
50	.85	150	.62	800	.42	5000	.29
60	.82	200	.57	900	.41	6000	.285
70	.77	300	.52	1000	.39	7000	.28
80	.79	400	.48	2000	.35	8000	.275
	.72	500	.46	3000	.33	9000	.27
						10000	.26

..ure pressure as determined from curves by factor in table above to obtain corrected pressure drop.

HOW TO ORDER: Specify Cash-Acme Type SY-70 and give size, service conditions, maximum pressure, maximum temperature, screwed or flanged connection and screen mesh or perforation.

PRESSURE DROP CHART
TYPE SY-70 STRAINERS



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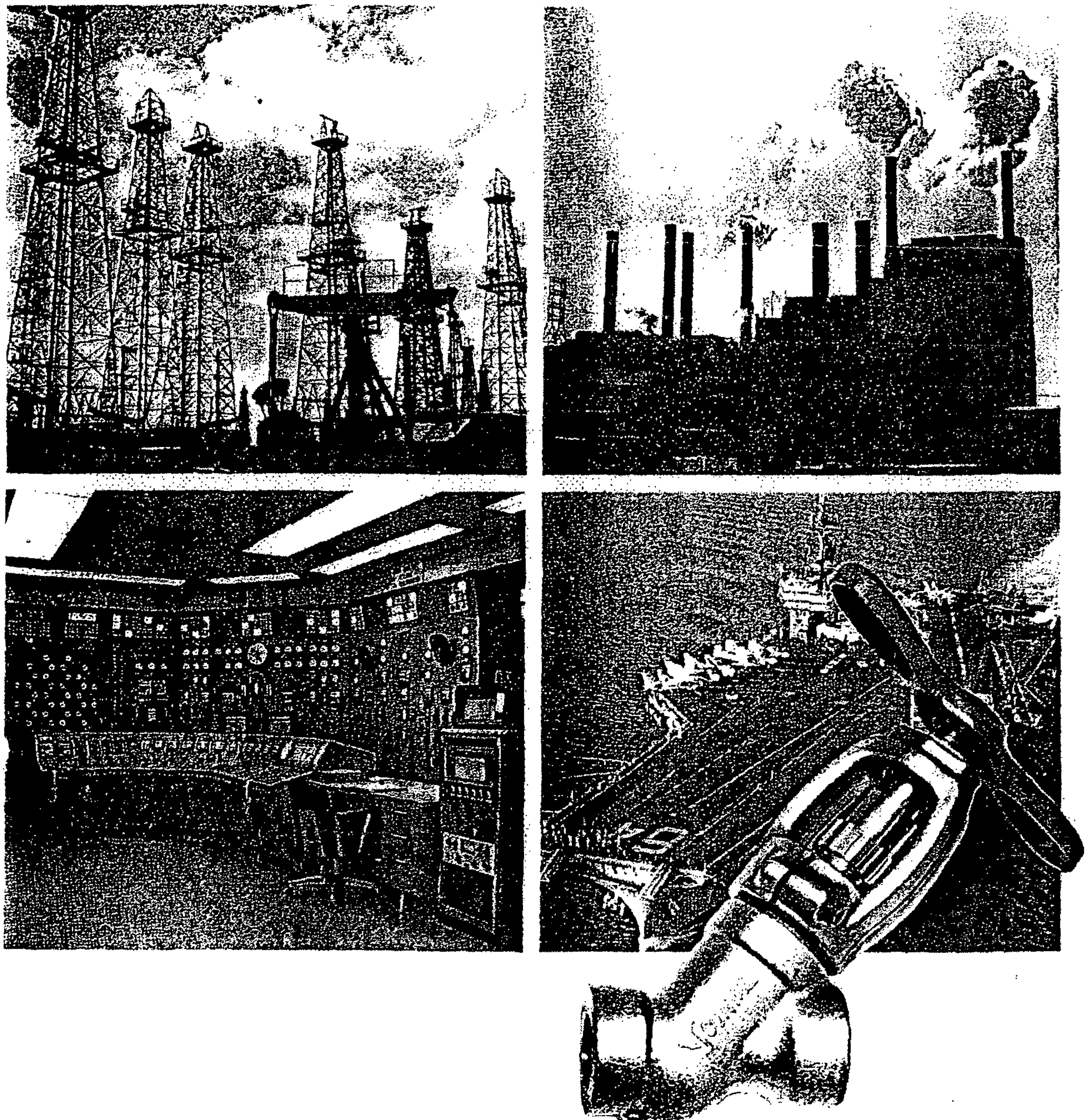
IP-CALC-06-00329 Rev. 1
Attachment 4
Page 2 of 2

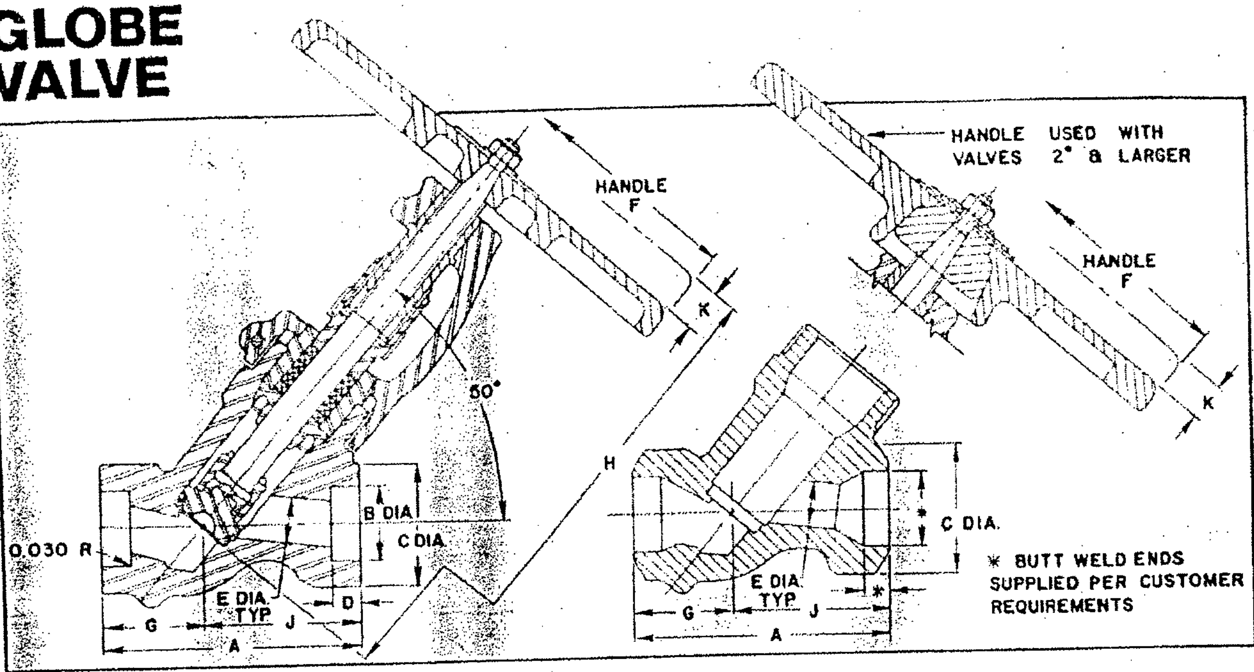


Conval INC.

• FORGED ALLOY STEEL • HIGH PRESSURE • HIGH TEMPERATURE CLAMPSEAL™ VALVES

IP-CALC-06-00329 Rev. 1
Attachment 5
Page 1 of 3

GLOBE VALVE



PRESSURE CLASS	SIZE	SIZE CODE	C_V	WT. LBS.	A SOC. WELD	A BUTT WELD	B	C	D	E	F	G SOC. WELD	G BUTT WELD	H	J SOC. WELD	J BUTT WELD	K
NOMINAL 900 INTERMEDIATE 1195	1/2	3D	6	5	3 3/4		.855	1 5/8	3/8	1/2	6 1/2	1 1/2		7 3/8	2 1/4		9/16
	3/4	5E	9.5	10	4 1/2	4 3/4	1.065	2 5/16	1/2	5/8	8	1 3/4		8 13/16	2 3/4	3	11/16
	1	5F	15.4	9	4 1/2	4 3/4	1.330	2 5/16	1/2	13/16	8	1 3/4		8 7/8	2 3/4	3	3/4
	1 1/4	7G	24	23	6 1/4	6 1/2	1.675	3 3/16	1/2	1	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	1 1/2	7H	38	22	6 1/4	6 1/2	1.915	3 3/16	1/2	1 1/4	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	2	8J	62	34	7 1/4		2.406	3 3/4	5/8	1 1/2	14	2 11/16		15	4 9/16		1 5/8
	2 1/2	9K	86	51	9	9 5/8	2.906	4	5/8	1 7/8	17	3 5/16	3 5/8	17	5 11/16	6	2 1/8
	3	10L	122	91	▲	12		4 7/8	▲	2 1/4	21	▲	5 5/16	18 1/4	▲	6 11/16	2 1/2
NOMINAL 1500 INTERMEDIATE 2155	1/2	3D	6	5	3 3/4		.855	1 5/8	3/8	1/2	6 1/2	1 1/2		7 3/8	2 1/4		9/16
	3/4	5E	9.5	10	4 1/2	4 3/4	1.065	2 5/16	1/2	5/8	8	1 3/4		8 13/16	2 3/4	3	11/16
	1	5F	15.4	9	4 1/2	4 3/4	1.330	2 5/16	1/2	13/16	8	1 3/4		8 7/8	2 3/4	3	3/4
	1 1/4	7G	24	23	6 1/4	6 1/2	1.675	3 3/16	1/2	1	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	1 1/2	7H	38	22	6 1/4	6 1/2	1.915	3 3/16	1/2	1 1/4	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	2	8J	62	34	7 1/4		2.406	3 3/4	5/8	1 1/2	14	2 11/16		15	4 9/16		1 5/8
	2 1/2	9K	86	51	9	9 5/8	2.906	4	5/8	1 7/8	17	3 5/16	3 5/8	17	5 11/16	6	2 1/8
	3	10L	122	91	▲	12		4 7/8	▲	2 1/4	21	▲	5 5/16	18 1/4	▲	6 11/16	2 1/2
NOMINAL 2500 INTERMEDIATE 3045	1/2	3C	4.1	6	3 3/4		.855	1 5/8	3/8	7/16	6 1/2	1 1/2		7 5/16	2 1/4		1/2
	3/4	5E	9.5	10	4 1/2	4 3/4	1.065	2 5/16	1/2	5/8	8	1 3/4		8 13/16	2 3/4	3	11/16
	1	5E	9.5	10	4 1/2	4 3/4	1.330	2 5/16	1/2	5/8	8	1 3/4		8 13/16	2 3/4	3	11/16
	1 1/4	7G	24	23	6 1/4	6 1/2	1.675	3 3/16	1/2	1	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	1 1/2	7G'	24	23	6 1/4	6 1/2	1.915	3 3/16	1/2	1	12	2 9/16		12 3/4	3 11/16	3 15/16	1 3/16
	2	8H	38	35	7 1/4		2.406	3 3/4	5/8	1 1/4	14	2 11/16		14 5/8	4 9/16		1 1/4
	2 1/2	9J	62	53	▲	9 5/8	2.906	4	5/8	1 1/2	17	▲	3 5/8	16 11/16	▲	6	1 13/16
	3	10K	86	93	▲	12		4 7/8	▲	1 7/8	21	▲	5 5/16	17 7/8	▲	6 11/16	2 1/8
NOMINAL 3500 INTERMEDIATE 4095	1/2	5D	6.4	11	4 1/2	4 3/4	.855	2 5/16	3/8	1/2	8	1 3/4		8 3/4	2 3/4	3	5/8
	3/4	5D	6.4	11	4 1/2	4 3/4	1.065	2 5/16	1/2	1/2	8	1 3/4		8 3/4	2 3/4	3	5/8
	1	5D	6.4	11	4 1/2	4 3/4	1.330	2 5/16	1/2	1/2	8	1 3/4		8 3/4	2 3/4	3	5/8
	1 1/4	7F	15.7	24	6 1/4	6 1/2	1.675	3 3/16	1/2	13/16	12	2 9/16		12 7/16	3 11/16	3 15/16	7/8
	1 1/2	8G	24	36	7 1/4	▲	1.915	3 3/4	1/2	1	14	2 11/16	▲	14 9/16	4 9/16	▲	1 3/16
	1 1/2	7F	15.7	24	▲	6 1/2	1.918	3 3/16	1/2	13/16	12	▲	2 9/16	12 7/16	▲	3 15/16	7/8
	2	9H	39	35	9	▲	2.406	4	5/8	1 1/4	17	3 5/16	▲	15 15/16	5 11/16	▲	2 1/16
	2	8G	24	38	▲	7 1/4	2.406	3 3/4	5/8	1	14	▲	2 11/16	14 9/16	▲	4 9/16	1 9/16
	2 1/2	9H	39	35	▲	9 5/8	2.906	4	5/8	1 1/4	17	▲	3 5/8	15 15/16	▲	6	[illegible]
	3	10J	62	96	▲	12		4 7/8	▲	1 1/2	21	▲	5 5/16	17 1/2	▲	6 11/16	2 3/4

▲ NOT AVAILABLE

IP-CALC-06-00329 Rev. 1
Attachment 5
Page 2 of 3

ORDERING INSTRUCTIONS

The CLAMPSEAL™ valve may be ordered by contacting your local Conval representative and specifying the following details:

- Size
- Pressure Rating
- Material
- End Connections
- Service or Maximum Temperature and Pressure
- Special Features

Conval INC.

CONVAL, INC., Field and Billings Rds., P. O. Box 427 Somers, CT 06071 Tel (203) 749-0761
TLX 955 485

Your Local Conval Representative

Printed in U.S.A.

Gaiewski, David C.

From: bob.calvin@rosscontrols.com
Sent: Thursday, June 30, 2005 2:44 PM
To: Gaiewski, David C.
Subject: Ross model 2671A8903

Hello David,

The older Ross model 2671A8903 has the same Cv of the current Ross model 2771B8011, Cv of 29.

Regards,
Bob Calvin
Mgr. Technical Services Department
Ross Controls - Lavonia, GA
bob.calvin@rosscontrols.com
Telephone (888)835-7677
Fax (706)356-3760 8 - 5 Eastern

Gaiewski, David C.

From: csileven@tycovalves.com
Sent: Thursday, June 30, 2005 12:13 PM
To: Gaiewski, David C.
Subject: Fw: Cash Acme 'B' Series pressure regulator valves

David,

John Brill of CASH CME asked that I respond to your inquiry. The 1 1/2" Type B Regulator hs a Cv of 10.6.

Regards,

Chuck
Tyco Valves & Controls
CASH VALVE Div

----- Forwarded by Chuck Sileven/US/Tyco on 06/30/2005 11:11 AM -----

jwb@cashacme.com
06/30/2005 11:03 AM

To: csileven@tycovalves.com
cc:
Subject: Fw: Cash Acme 'B' Series pressure regulator valves

John Brill
Director of OEM Sales

CASH ACME

A Division of the
Reliance Worldwide Corporation
Ph: (256) 775-8179
Fax: (256) 775-8238

http://www.cashacme.com

----- Forwarded by John Brill/CASHACME/US on 06/30/2005 11:01 AM -----

"Gaiewski, David C."
<DGaiewski@protopower.com>

06/30/2005 10:24 AM

<technicalsupport@cashacme.com>

cc

Subject
Cash Acme 'B' Series pressure regulator valves

I am looking for hydraulic resistance information for 1-1/2" Cash Acme 'B' Series pressure regulator valves. I am trying to figure the wide open Cv of the valve. Your capacity charts (Bulletin REG-3) give curves for initial pressure on a graph of delivery pressure vs. capacity. The valve in my system is supposed to regulate downstream (delivery) air pressure to 150 psig. If the inlet (initial) pressure falls below this set pressure, I assume the valve will go full open. At that point, what is the hydraulic resistance of the valve (Full Open Cv)

Thanks,

David Gaiewski
Proto-Power Corporation
(860) 405-3115

Gaiewski, David C.

From: Stevenson, Ted [Ted.Stevenson@FairbanksMorse.com]
Sent: Thursday, August 18, 2005 12:06 PM
To: Gaiewski, David C.
Subject: FW: Indian Point Energy Center Unit 2 EDG Starting Air Requirements

The numbers given below are based on the assumed average air consumption per start of 50 cu ft, which appears to be the result of considerable testing done in the past by Alco. As stated this is an average number and needs to be taken with caution as the air consumption is a function of a number of variables. In this respect please note that the amount of air required per start is determined primarily by a) The total inertia of the system, *i.e. engine, generator, flywheel, coupling, etc, b) Lube oil and jacket water temperature*, these units should be equipped with a keep warm system so this should take care of the temperatures, c) torque capacity of the air starter.
The calculation below is for consecutive startings without recharging of the air tank, and again the minimum starting pressure of 90 psi may vary to a certain degree.
Ultimately the customer could run a test doing consecutive starts and confirm air consumption and minimum starting pressure. However and based on past experience it is safe to assume that for the NYPA units, the number of starts will be between 4 to 6, as stated below.

From: Gaiewski, David C. [mailto:DGaiewsk@protopower.com]
Sent: Thursday, August 11, 2005 9:53 AM
To: Stevenson, Ted
Cc: Bubniak, Jerry
Subject: Indian Point Energy Center Unit 2 EDG Starting Air Requirements

Ted,

Can you confirm the following statement made by GE Canada in response to NYPA questions in April 1991 (See excerpt attached):

> It is accepted that 50 ft^3 of free air is sufficient to start the 16 cylinder 251 engine using one air motor and a crank time duration of approximately 3.0 seconds. Since two motors are applied for redundancy, the usage is 100 ft^3 free air per start. The 53 ft^3 air storage tank requires 577 ft^3 of free air to reach 250 psig. A minimum pressure of 90 psig in the storage tank is required for reliable starts.
>
> Calculation:
>
> $$No.\ of\ Starts = \frac{(53)(250-90)}{(14.7)(2\times 50)} = \frac{8480}{1470} = 5.7 \text{ starts from available air supply}$$
>
> This has been verified repeatedly in tests resulting in acceptance of 4 starts as being a safe, reliable number for our customers to use.

The complete, formal response could not be found in Entergy's records.

Thank you,

David Gaiewski
Proto-Power Corporation
(860) 405-3115

<<EDGStartingAir.pdf>>

IP-CALC-06-00329 Rev 1
Attachment 8
Page 2 of 2

Compressible Flow Manual

by

Bailey M. Coulter, Jr.

A handbook for the design
of compressible flow piping
systems and a complete source
of gas properties.

IP-CALC-06-00329 Rev. 1
Attachment 9
Page 1 of 14

Fluid Research Publishing
P.O. Box 40853
Houston, Texas 77240-0853

Price: $18.00
Printed in U.S.A.
First Print in 1984

IP-CALC-06-00329 Rev. 1
Attachment 9
Page 2 of 14

Chapter 4

Compressible Flow

Introduction

In this chapter, equations are established for adiabatic flow in a constant area pipe with friction, flow in a frictionless inlet nozzle, adiabatic flow in an abrupt expansion with losses, frictionless flow in an abrupt contraction, and flow through nozzles, venturi meters, and orifices. The solutions to the main flow equations are presented in design charts. The design charts have been prepared for values of the isentropic exponent k of 1.0, 1.2, 1.3, 1.4, and 1.67. The design chart for a value of $k = 1.0$ corresponds to adiabatic flow of a hypothetical gas having an exponent of 1.0 or to isothermal flow of any gas.

The development of the flow equations is based on the standard assumptions typical for flow in a closed conduit. These assumptions are: (1) the flow is steady and one dimensional, (2) the fluid can be described by the perfect gas law, (3) the flow is adiabatic, and (4) the effect of elevation change is negligible.

Effect of Friction

An understanding of the effect of friction on the compressible flow process is required to evaluate flow problems correctly. The direct effect of friction is a loss of total pressure. This is easily shown by Bernoulli's equation for incompressible flow. (Elevation terms are negligible and have been omitted).

$$\left(P_{s1} + \rho\frac{V_1^2}{2g_c}\right) - \left(P_{s2} + \rho\frac{V_2^2}{2g_c}\right) = \text{Friction losses}$$

Since the total pressure P_t is equal to the sum of the static and velocity pressure, then

$$P_{t1} - P_{t2} = \text{Friction losses}$$

The total pressure is a measure of the total available energy at any cross section of the piping system and continually decreases in the direction of flow as momentum is removed by wall friction.

The static and velocity pressures are mutually convertible, and either can increase or decrease in the direction of flow with changes in pipe area.

Figure 4.1 shows graphically the relationship between the total pressure, static pressure, and velocity (or kinetic energy) of an incompressible fluid flowing through a constant area pipe.

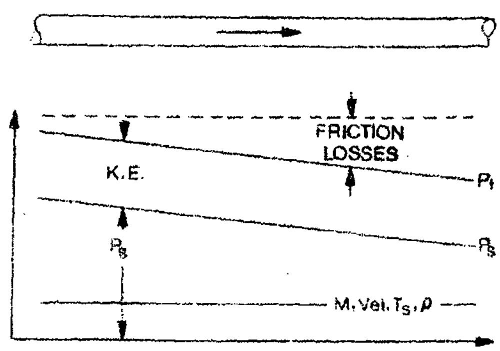


Figure 4.1. *Incompressible flow with friction losses.*

The effect of friction in compressible flow is also the loss of total pressure. The static pressure, being a component of the total pressure, also decreases. According to the equation of state for a gas, density is proportional to static pressure; thus, a decrease in static pressure causes a corresponding decrease in gas density. As a result, the velocity, and hence the Mach number, must increase to accommodate the increase in volumetric flow rate (the mass flow rate remaining constant). Since friction losses increase with the square of the velocity, the total and static pressure losses per unit length of pipe begin to increase rapidly. Figure 4.2 shows the relationship between the flow variables for compressible flow with friction.

Choked Flow

Extending the length of pipe shown in Figure 4.2, we may expect further reductions in static pressure and continuing increases in velocity and Mach number. However, from thermodynamics it can be shown that the effect of friction in a constant area pipe is to accelerate the flow to $M = 1.0$. When this condition is reached, the flow is said to be choked.

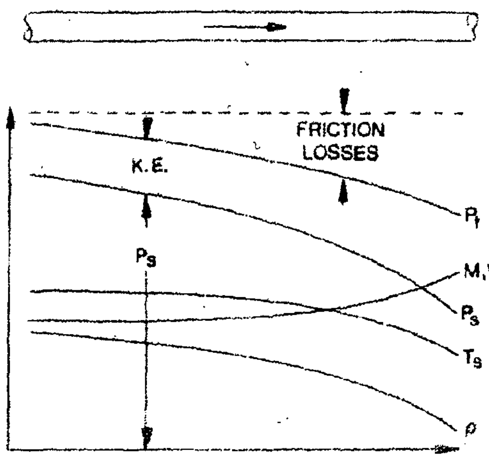


Figure 4.2. Compressible flow with friction losses.

In other words, the maximum flow rate occurs at the highest velocity, and no further increase in flow can occur. (Supersonic velocities can be obtained only in convergent-divergent nozzles whereby the fluid accelerates to $M = 1.0$ in the convergent section. If there is a reduced pressure in the divergent section allowing the gas to expand, the fluid can accelerate to supersonic velocities. The area change in the divergent section must be gradual. The occurrence of supersonic velocities in an industrial system is highly unlikely, and thus, is beyond the scope of this handbook.)

Further, for a constant area pipe, it can be shown that $M = 1.0$ can be reached only at the end of the pipe. The potential for accelerating the flow to $M = 1.0$ depends upon the difference between the upstream and downstream pressures. The value of the pressure difference is unique for each piping geometry.

If the pressure difference exceeds that required to accelerate the flow to $M = 1.0$ at the pipe exit, the exit Mach number will be $M = 1.0$, and the static pressure at the exit will be greater than ambient. The excess pressure at the exit (exit pressure - ambient pressure) will be dissipated outside of the pipe as expansion shock waves as shown in Figure 4.3. Physically, this is observed as a rapid increase in the exhaust noise levels.

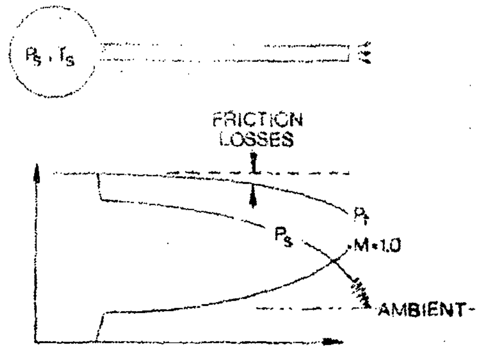


Figure 4.3. Compressible flow with sonic velocity at exit.

If the pressure difference is not large enough to accelerate the flow to $M = 1.0$ at the pipe exit, the flow will be subsonic everywhere, and the static pressure at the pipe exit will be the same as the ambient pressure, as shown in Figure 4.4. The static pressure at the end of the pipe can never be less than ambient pressure.

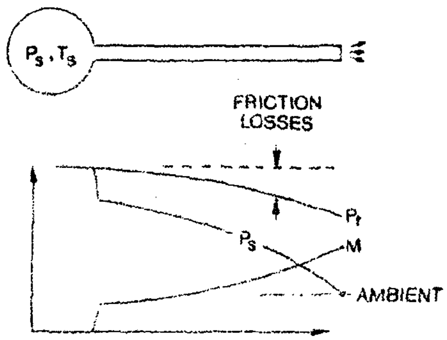


Figure 4.4 Compressible flow with subsonic velocity.

The above discussion on choking has been based upon flow in a constant area pipe. Choked flow, can also occur within a piping system at area changes, i.e., at contractions and at expansions. Further, $M = 1.0$ can occur at several area changes simultaneously; however, only at one location will the maximum flow be "choked". Several example problems have been included to illustrate this occurrence.

Adiabatic Flow Process

Consider a flow process in a piping system which takes place with no heat exchange between the gas and its surroundings.

This type of process is called an adiabatic process. According to the steady flow energy equation applied to a mass of gas undergoing an adiabatic process between the reservoir 0 and a given cross-section x (Figure 4.5), the total energy of the fluid must be the same at every cross section, that is

$$h_{to} = h_x + \frac{V_x^2}{2gcJ} = \text{constant}$$

where the enthalpy h is equal to the sum of internal energy u and flow energy pv. The energy equation indicates that the total enthalpy h_t, which represents the enthalpy of a fluid at rest, is equal to the sum of the enthalpy and kinetic energy of the fluid at any point.

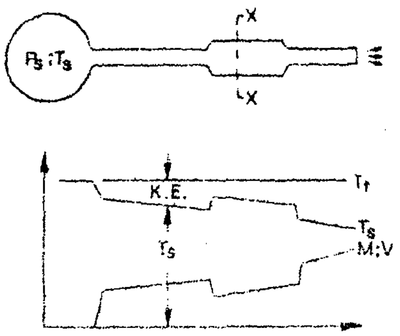


Figure 4.5. Relationship between static and total temperatures in an adiabatic process.

By substituting elementary thermodynamic expressions, the energy equation may be written as

$$T_{t0} = T_{sx} + \frac{k-1}{2}\,\frac{V_x^2}{kgcR} = \text{constant}$$

which, incidently, is the total temperature equation (3.3). In its simplified form, equation (3.3) reduces to

$$T_{t0} = T_{sx}\left(1 + \frac{k-1}{2} M_x^2\right) = \text{constant}$$

Inspection of the energy equation in this form reveals that the total temperature, which represents the temperature of a fluid at rest, is equal to the sum of the static temperature and kinetic energy at any cross section; i.e., the total temperature is a constant of the flow process. Further, any changes in the kinetic energy (or velocity) will result in an opposite change in the heat energy (temperature). This is shown descriptively in Figure 4.5.

Notice that pipe friction was not mentioned in the definition of an adiabatic process nor was it introduced in the energy equation. Pipe friction and turbulence are simply conversions of internal mechanical energy into heat energy. The total energy of the system remains the same.

Isentropic Flow Process

In some piping elements, it is convenient to assume the flow process as being without friction. The assumption of negligible friction forces (frictionless) for the flow nozzle in Figure 4.6 is appropriate because the flow passage is short and smooth. Further, the shape of the nozzle causes the flow stream to converge which prevents turbulence. Without losses, the total pressure is constant. That is

$$P_{t0} = P_{t1}$$

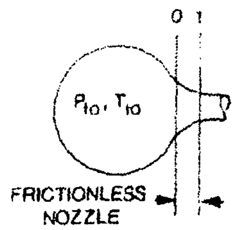


Figure 4.6.

Also, since the surface area of the nozzle is small, the heat loss or gain through the nozzle wall can be considered negligible. Thus, flow through a nozzle can be considered adiabatic.

Processes that are both frictionless and adiabatic are referred to as isentropic.

Flow Through an Inlet Nozzle

The primary elements of all piping systems are a reservoir, an inlet nozzle, and a length of pipe. In the typical flow problem, the fluid properties in the reservoir are known and the changes in properties along the pipeline are to be determined. However, the properties at the pipe entrance must be determined before preceding with property changes along the pipeline. To relate the properties in the reservoir to the pipe inlet, consider that the reservoir is connected to the pipe by a nozzle. Futher, it is advantageous to consider the nozzle as frictionless and without heat exchange to the surroundings, that is, an isentropic flow nozzle, Consider the isentropic nozzle shown in Figure 4.6.

The static pressure at location 1 can be related to the total pressure of the reservoir by means of the total pressure equation (3.2) since $P_{t0} = P_{t1}$.

$$\frac{P_{t1}}{P_1} = \left[1 + \frac{k-1}{2} M_1^2\right]^{\frac{k}{k-1}}$$

The static temperature at location 1 can be related to the total temperature of the reservoir by means of the total temperature equation (3.4) since $T_{t0} = T_{t1}$.

$$\frac{T_{t0}}{T_{s1}} = 1 + \frac{k-1}{2} M_1^2$$

If the Mach number at location 1 is unknown, it can be determined from the upstream properties using the isentropic mass flow equation (3.12).

$$M\left[1 + \frac{k-1}{2} M^2\right]^{-\frac{k+1}{2(k-1)}} = \frac{\dot{m}}{A} \frac{1}{P_{t0}} \sqrt{\frac{RT_{t0}}{kg_c}}$$

The charts presented in Figures 3.1, 3.2, and 3.5 can be utilized to solve these equations.

Generally, the pipe connection to the reservoir is not made with a nozzle as perfect as shown in Figure 4.6. However, the nozzle may still be treated as frictionless and the losses attributed to the nozzle accounted for as additional equivalent pipe lengths.

Adiabatic Flow with Friction in a Constant Area Pipe

The vast majority of all compressible flow problems in process industries can be represented by the adiabatic flow process with friction. As a guide, the following cases have negligible heat transfer through the pipe walls, and thus, closely approximate the adiabatic theory.

1. Insulated piping.
2. Processes in which the temperature difference between the fluid and ambient are small, e.g., flow from a storage vessel where the fluid temperature is at or near ambient.
3. Pipes which are reasonably short, and the effects on the fluid properties due to heat transfer are negligible compared to the fluid acceleration effects.
4. Processes in which the flow duration are completed before heat transfer is established.

The equations relating the change in static pressure and static temperature due to friction in a constant area pipe for an adiabatic process may be found in any [illegible] equations, which are called Fanno equations, are given below for the purpose of reference.

$$\frac{P_2}{P_1} = \frac{M_1}{M_2}\sqrt{\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}}$$

$$\frac{T_{s2}}{T_{s1}} = \frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}$$

$$f\frac{L}{D} = \frac{1}{kM_1^2} - \frac{1}{kM_2^2} + \frac{k+1}{2k}\ln\frac{M_1^2[2+(k-1)M_2^2]}{M_2^2[2+(k-1)M_1^2]}$$

Because of the complexity in solving the equations, the solutions have been charted. The charts are self-explanatory; however, a few comments are necessary. It is necessary to know the value of the friction factor to determine the pipe geometry factor K. If the initial flow data is insufficient to allow a determination of the friction factor, then an initial assumption of $f = 0.015$ can be made. This will allow a solution to the problem. By iteration, the actual value of f can be found.

The equations used to develop the charts are based upon a constant friction factor. However, in compressible flow the Reynolds number varies along the pipe due to changes in the fluid's velocity and density. Since the friction factor is a weak function of Reynolds number, an assumption of a constant friction factor based upon inlet properties is justified. When precision is wanted, an average friction factor can be made based upon the inlet and outlet gas properties. However, if the flow accelerates to $M = 1.0$ at the exit, averaging the friction factor will lead to error since the increase in velocity is exponential. Rapid changes in velocity occur in the last 5 percent of the pipe length.

The charts provide a direct method of calculating static pressure changes between two locations in a constant area pipe. For example, if the flow rate, static pressure, and static temperature are known at one location, the Mach number can be determined using the mass flow equation (3.10). Entering the charts with Mach number, the static pressure ratio between two pipe locations can be read.

In many problems, the static temperature is not known. In this case, the Mach number can be determined from the adiabatic mass flow equation (3.11) using the total temperature in the reservoir.

Two sets of charts have been provided allowing solutions to proceed from either an upstream or down stream location. Further, the charts may be used simultaneously to determine the Mach number in the unknown location. After determining the Mach number, the static temperature at the unknown location [illegible] (3.4).

Charts are provided for isentropic exponent values of 1.0, 1.2, 1.3, 1.4, and 1.67. It is of interest that at a value of $k = 1.0$, the equations for adiabatic flow of a gas with friction in a constant area pipe exactly coincide with isothermal, frictional pipe flow of any perfect gas. Thus, the chart for $k = 1.0$ can be used to evaluate the static pressure changes for isothermal flows without any approximations. However, in the case of isothermal flow, the choked flow condition is established at a value of $M = 1/\sqrt{k}$, rather than unity. This is not of importance since choked flow in the isothermal process is academic; the isothermal assumption is valid only with flows at low Mach numbers. When treating a flow process along the pipe as isothermal, it is still justified to treat the flow process through the pipe entrance and changes in cross-sectional area as adiabatic. For flow through these elements, the isentropic exponent based upon the gas properties should be used.

Abrupt Enlargements

The flow loss in abrupt enlargements (Figure 4.7) is due to turbulence created by the high velocity jet stream undergoing a rapid deceleration as it expands into the larger area. This loss causes a drop in the total pressure, that is

$$P_{t1} - P_{t2} = \text{Turbulence losses}$$

and for an incompressible fluid, the local loss for an abrupt expansion can be written as

$$(P_{t1} - P_{t2})_{inc} = (1 - A_1/A_2)^2 \rho \frac{V_1^2}{2g_c}$$

More important to the designer is the change in static pressure which can be determined from

$$(P_{s2} - P_{s1})_{inc} = \frac{\rho V_1^2}{g_c}[(A_1/A_2) - (A_1/A_2)^2]$$

The compressible flow equations for an abrupt expansion based upon an adiabatic, but not isentropic, process are

$$M_2 = \left[\frac{1 - 2kC^2 - \sqrt{1 - 2(k+1)C^2}}{2k^2C^2 - k + 1}\right]^{1/2}$$

where

$$C = \frac{M_1\left[1 + \frac{k-1}{2}M_1^2\right]^{1/2}}{1 + kM_1^2 + (A_2/A_1 - 1)}$$

and

$$\frac{P_2}{P_1} = \frac{A_1 M_1}{A_2 M_2}\sqrt{\frac{2 + (k-1)M_1^2}{2 + (k-1)M_2^2}}$$

Because of the complexity of these equations, their solutions have been charted. By entering the charts with the inlet Mach number, we can read the exit Mach number and the static pressure ratio across the expansion. The static temperature following the enlargement may be determined from the total temperature equation (3.4).

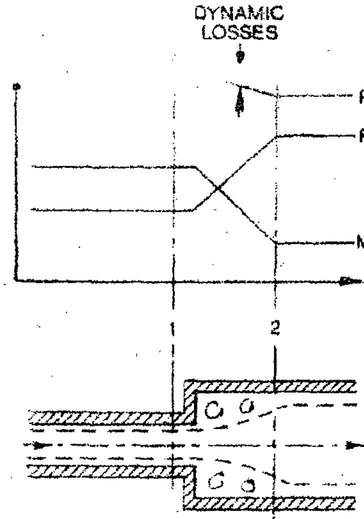


Figure 4.7 Adiabatic flow through an abrupt expansion.

Like incompressible flow, the charts always show a static pressure regain and a decrease in velocity or Mach number as the fluid decelerates upon entering the larger pipe. This is always true as long as the flow is subsonic. When the inlet Mach number is unity, the charts give the lowest value of the exit Mach number and the highest value of the downstream pressure that is possible. Obviously, the downstream pressure can be reduced and the exit Mach number increased without affecting the upstream conditions since pressure changes cannot be transmitted upstream through a section where $M = 1.0$. In other words, when $M_1 = 1.0$, the abrupt expansion acts as a flow discontinuity and the downstream properties cannot be directly determined from the inlet conditions. In this case, the calculations to determine the real properties after the expansion must proceed from the outlet of the piping system toward the abrupt expansion.

Abrupt Contractions

Like abrupt expansions, the local loss due to turbulence of an abrupt contraction (Figure 4.8) is manifested as a loss in total pressure, and for an incompressible fluid, the loss can be written as

$$(P_{t1} - P_{t2})_{inc} = K_c \rho \frac{V_2^2}{2g_c}$$

where K_c is the contraction loss coefficient and can be defined as

$$K_c = K_t (1 - A_2/A_1)$$

where K_t, an empirical coefficient = 0.5.

The change in static pressure across a contraction can be determined from

$$(P_{s2} - P_{s1})_{inc} = \rho \frac{V_2^2}{2g_c} [-1.5 + K_t A_2/A_1 + (A_2/A_1)^2]$$

The equations for compressible flow through an abrupt contraction are based upon the isentropic process. The basis for this process is the same as described for the inlet nozzle, that is, converging flow streams create only minor disturbances. Of course, if conditions warrant considering the losses, the losses can be accounted for as additional equivalent pipe lengths. The equations, listed below, have been charted to provide rapid solutions.

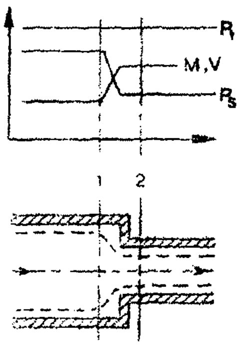


Figure 4.8

$$\frac{A_2}{A_1} = \frac{M_1}{M_2} \left[\frac{2 + (k-1)M_1^2}{2 + (k-1)M_2^2} \right]^{-\frac{k+1}{2(k-1)}}$$

and

$$\frac{P_{s2}}{P_{s1}} = \left[\frac{2 + (k-1)M_1^2}{\text{[illegible]}} \right]^{\frac{k}{k-1}}$$

By entering the charts with the inlet Mach number, the exit Mach number and static pressure ratio can be read. The static temperature may be determined from the total temperature equation (3.4).

Flow Meters

The Venturi tube, flow nozzle, and thin-plate, square-edged orifice are installed in piping systems to measure the flow rate. They are reasonably accurate while economic to install and require little, if any, maintenance. All of these flow elements present a constricted flow area within the pipe thereby causing an acceleration of the fluid and a decrease in static pressure. The difference between the static pressure ahead of the flow restriction and static pressure in the flow restriction is proportional to the square of the velocity in the restriction. Therefore, this pressure difference can be used in basic theoretical equations to determine flow rate. The accuracy of the equations can be improved by the use of flow coefficients which are based upon the specific geometry of the flow element, location of the pressure taps used to measure the differential pressure, surface roughness, Reynolds number, etc. Differential pressure meters have been studied extensively by the A.S.M.E. Committee on Fluid Meters and their reports should be consulted where accurate results are required.

Consider the nozzle shown in Figure 4.9. The theoretical flow equation for an isentropic process between the upstream pipe and the nozzle throat can be written as

$$\dot{m} = A_2 Y \sqrt{\frac{2g_c \rho (P_{s1} - P_{s2})}{1 - \beta^4}} \quad (4.1)$$

where

$$Y = \left[r^{2/k} \left(\frac{k}{k-1} \right) \left(\frac{1 - r^{(k-1)/k}}{1 - r} \right) \left(\frac{1 - \beta^4}{1 - r^{2/k}\beta^4} \right) \right]^{1/2} \quad (4.2)$$

and

$$r = P_{s2}/P_{s1} \, ; \, \beta = d_2/d_1$$

For an incompressible fluid, $Y = 1.0$.

The accuracy of equation (4.1) can be improved by introducing an additional factor called the discharge coefficient C. The resulting equation is

$$\dot{m} = A_2 C Y \sqrt{\frac{2g_c \rho (P_{s1} - P_{s2})}{1 - \beta^4}} \quad (4.3)$$

For both nozzles and Venturi tubes with Reynolds number of 100,000 or greater, the value of the discharge coefficient is approximately 1.0.

A review of equation (4.3) reveals that, in the form presented, the equation is used to evaluate the flow rate using the measured differential pressure across an *existing* nozzle. The actual selection of a nozzle is based upon selecting a diameter ratio that will produce a meaningful pressure differential range between the lowest and highest flow rate expected, and within the limits of the pressure measuring device. Large ratios of D_2 / D_1 are favored since the pressure drop across the flow meter represents an energy loss. The determination of pressure drop of a compressible fluid across a nozzle using the above equation requires a trial and error solution.

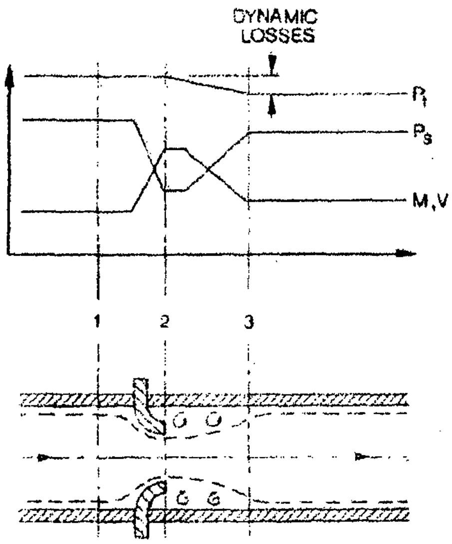


Figure 4.9 Compressible flow through a flow nozzle.

The standard flow meter equation is simply another form of the isentropic mass flow equation (3.12). Further, the equations applicable to gas flow in nozzles are the same equations given for determining the compressible flow through an abrupt contraction. Using the charts provided for abrupt contractions, rapid solutions are possible for determining the properties at the nozzle throat.

Following the nozzle throat, the gas expands into the downstream pipe creating turbulence similar to an abrupt enlargement. Obviously, the expanding flow is no longer isentropic. The losses due to the turbulence can be accounted for, and the properties in the downstream pipe, location 3, determined from the equations and charts presented for compressible flow through an abrupt enlargement using the nozzle throat properties previously determined.

Flow characteristics of a Venturi tube and a nozzle are identical except the flow stream of the Venturi tube is controlled downstream of the nozzle throat resulting in little, if any, turbulence. In other words, the Venturi tube (Figure 4.10) may be considered as frictionless and without turbulence throughout the length of the tube. Then, the exit properties are the same as the entrance properties, that is

$$P_{t1} = P_{t3} \text{ and } T_{t1} = T_{t3}$$

changes in cross-sectional area, are determined from the same equations and charts presented for the nozzle, i.e., flow through an abrupt contraction.

In both the nozzle and the Venturi tube, the fluid stream is guided by the walls and completely fills the tube or nozzle.

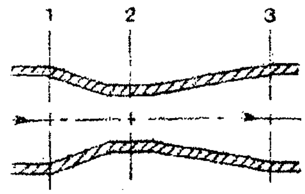


Figure 4.10 Venturi tube.

In an orifice (Figure 4.11) the stream is not guided as it passes through the orifice; therefore, the stream continues to decrease. The area of minimum cross-section is called the vena contracta. Because the flow stream is not guided, the overall pressure loss is greater for the orifice than either the nozzle or the Venturi tube.

The mass flow through the orifice can be determined from equation (4.3) using a discharge coefficient of C = 0.61 for Reynolds number greater than 50,000. The factor Y for an orifice is given by

$$Y = 1 - (0.410 + 0.350\beta^4)(1 - r)/k \quad (4.4)$$

Like the nozzle, the throat properties for the orifice may be calculated accurately for Mach numbers at the vena contacta upto 0.2 using the equations and charts presented for flow through an abrupt contraction. The throat area used must be the area of the vena contracta which can be found from

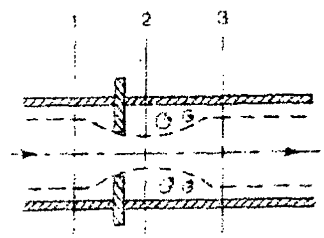


Figure 4.11 Orifice.

$$A_2 = \frac{C}{\sqrt{1-\beta^4}} A_{orifice} \quad (4.5)$$

where

$$\beta^2 = \frac{A_{orifice}}{A_1} \quad (4.6)$$

The change in properties between the vena contracta and the downstream pipe can be determined from the equations and charts given for an abrupt enlargement using the area of the vena contracta determined above.

Effects of Fittings and Valves

It is general practice to assign a loss coefficient to pipe fittings, valves and other components, based upon empirical data. The accuracy of this technique is considered acceptable in compressible flow when the static pressure loss across the component is a small percentage of the absolute pressure and when the gas velocities are less than $M = 0.3$.

When components have a marked contraction in cross-sectional area, a flow analysis of the component should be made since the contracted area may be a controlling factor in the discharge rate; i.e., $M = 1.0$ may exist in this section. This is an actual occurrence in pressure regulators and throttling valves when the static pressure drop across the component is approximately 50% of the upstream pressure. The velocity or Mach number within a component can be determined easily by assuming the component is an isentropic nozzle. Then, using the charts for isentropic flow between the inlet and the throat area, and the charts for an abrupt expansion between the throat area and the outlet, reasonable values of the changes in properties and Mach numbers can be made.

Incompressible Flow Theory Comparison

There are many occasions in which the incompressible flow theory is useful when dealing with gases. The equation for computing frictional pressure losses for an incompressible fluid in a constant area pipe is

$$P_{t1} - P_{t2} = \left(f\frac{L}{D}\right)\rho\frac{V_1^2}{2g_c}$$

Since the flow process occurs at constant density and constant velocity, Bernoulli's equation reduces to

$$P_{t1} - P_{t2} = P_{s1} - P_{s2}$$

and thus,

$$P_{s1} - P_{s2} = \left(f\frac{L}{D}\right)\rho\frac{V_1^2}{2g_c}$$

However for gases, this equation can be simplified by introducing the Mach number equation and the equation of state, and after rearrangements, yields

$$\frac{P_{s2}}{P_{s1}} = 1 - \left(f\frac{L}{D}\right)\frac{k}{2}M_1^2 \tag{4.7}$$

A review of this equation shows that for a given pipe geometry fL/D and isentropic exponent k, the static pressure drop due to friction is solely a function of the Mach number. Plotting equation (4.7) on the charts given for adiabatic flow in a constant area pipe with friction shows that the incompressible flow equation coincides exactly with the compressible flow equation in the region of low Mach numbers and small static pressure drops. (Equation 4.7 plots as a straight line on a log-log scale.) The difference between the curves shown on the charts and a straight line at large pressure drops is due to the change in density of the fluid as it accelerates along the pipeline.

Equation (4.7) is useful when the value of the isentropic exponent k, does not coincide with the charts, or when extrapolation must be made off the charts.

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ENGLISH UNITS
Summary of Equations

Equation of State

$$Pv = RT \qquad 144pv = RT$$

$$R = \frac{R_u}{M_w} \qquad \rho = \frac{1}{v}$$

Velocity of Sound

$$c = \sqrt{kg_c RT}$$

Mach Number

$$M = \frac{V}{c} \qquad M = \frac{V}{\sqrt{kg_c RT}}$$

Flow Rate Conversion

$$\dot{m} = Q\rho = \frac{Q}{v}$$

Mass Flow Equation

$$\dot{m} = \rho A V \qquad \dot{m} = 0.06787\,\frac{(SCFM)}{R}$$

$$M = \frac{\dot{m}\,1}{A P_s}\sqrt{\frac{RT_s}{kg_c}}$$

$$M = 0.2245\,\frac{\dot{m}}{d^2 p_s}\sqrt{\frac{RT_s}{k}}$$

$$M\left[1 + \frac{k-1}{2}M^2\right]^{1/2} = 0.2245\,\frac{\dot{m}}{d^2 p_s}\sqrt{\frac{RT_t}{k}}$$

$$M\left[1 + \frac{k-1}{2}M^2\right]^{-\frac{k+1}{2(k-1)}} = 0.2245\,\frac{\dot{m}}{d^2 p_t}\sqrt{\frac{RT_t}{k}}$$

Flow through Orifices and Nozzles

$$\dot{m} = 0.525 d^2 C Y \sqrt{\rho_1 \frac{(p_{t1} - p_{t2})}{1 - \beta^4}}$$

Total Pressure Equation

$$\frac{P_t}{P_s} = \left[1 + \frac{k-1}{2}M^2\right]^{\frac{k}{k-1}}$$

Total Temperature Equation

$$\frac{T_t}{T_s} = 1 + \frac{k-1}{2}M^2$$

$$R_e = \frac{VD\rho}{\mu} \qquad R_e = 124\,\frac{Vd\rho}{\mu_e}$$

Loss Coefficient

$$K = f\frac{L}{D}$$

SYMBOLS

Symbol	Description	Units
A	Area	ft^2
c	Velocity of Sound	ft/sec
C	Coefficient of Discharge	dimensionless
d	Inside Diameter	in.
D	Inside Diameter	ft
f	Friction Factor	dimensionless
g_c	Proportionality Constant	$32.2\ lb_m\text{-}ft/lb_f\text{-}sec^2$
k	Isentropic Exponent	dimensionless
K	Loss Coefficient	dimensionless
L	Length	ft
$\dot{m}$	Mass Flow Rate	lb_m/sec
M	Mach Number	dimensionless
M_w	Molecular Weight	$lb_m/mole$
p	Pressure	lb_f/in^2
P	Pressure	lb_f/ft^2
Q	Volumetric Flow Rate	ft^3/sec
R	Specific Gas Constant	$lb_f\text{-}ft/lb_m\text{-}°R$
R_e	Reynolds Number	dimensionless
R_u	Universal Gas Constant	$1545\ lb_f\text{-}ft/mole\text{-}°R$
$SCFM$	Flow Rate in Standard Cubic Feet Per Minute (14.7 psia and 60°F)	std. ft^3/min
T	Temperature	°R
v	Specific Volume	ft^3/lb_m
V	Velocity	ft/sec
Y	Expansion Factor	dimensionless
β	Ratio of Diameters	dimensionless
ρ	Density	lb_m/ft^3
μ	Viscosity	$lb_m/ft\text{-}sec$
μ_e	Viscosity	centipoise

2. $T_{s1} = 530/[1.0 + (0.2 \times 1.0^2)] = 441.66°R$

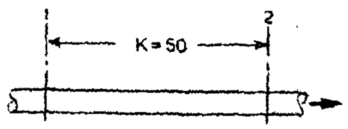
Also, the static temperature can be determined from Figure 3.2.

3. $1.0 = \dfrac{0.2245\ \dot{m}}{2.067^2 \times 87.0} (53.35 \times 441.66/1.4)^{0.5}$

$\dot{m} = 12.764\ lb_m/sec$

4. The isentropic mass flow equation could have been used to determine the flow rate using the total properties in the reservoir; however, it is simpler to determine the static pressure and temperature and with these properties, determine the flow rate using the mass flow equation.

Problem 3



Air at a static pressure of 100 psia flows by station 1 at a Mach number of 0.093. Determine the total and velocity pressure at station 1 and the static, total, and velocity pressure at station 2. The pipe geometry coefficient, K, is 50.0. The flow process is adiabatic with friction. (k = 1.4)

$$\frac{P_t}{P_s} = \left[1 + \frac{k-1}{2} M^2\right]^{\frac{k}{k-1}}$$

1. $p_{t1} = 100 \times [1.0 + (0.2 \times 0.093^2)]^{3.5}$
$= 100.606$ psia

2. $p_{v1} = p_{t1} - p_{s1} = 100.606 - 100.0$
$= 0.606$ psia

3. From Figure 4.15b, at $M_1 = 0.093$ and $K = 50.0$, read $P_{s2}/P_{s1} = 0.619$.
$p_{s2} = 0.619 \times 100.0 = 61.9$ psia

4. From Figure 4.19a, at $K = 50.0$ and $P_{s2}/P_{s1} = 0.619$; read $M^2 = 0.150$.

5. $p_{t2} = 61.9 \times [1.0 + (0.2 \times 0.15^2)]^{3.5}$
$= 62.88$ psia

6. $p_{v2} = p_{t2} - p_{s2} = 62.88 - 61.9 = 0.98$ psia

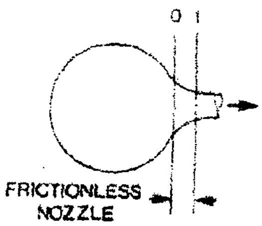
7. All of the properties have now been determined. It is of interest to calculate the total pressure loss from station 1 to 2 which represents the irrecoverable loss due to pipe friction.

100.606 − 62.88 = 37.726 psia

Generally, the designer is only interested in the loss of static pressure which is

100.0 − 61.9 = 38.1 psia

Problem 4



A reservoir-piping system has been selected for a design velocity at the pipe inlet, station 1, of 100 ft/sec. The reservoir contains air at 114.7 psia and 540°R. The volumetric flow rate is 1572 *SCFM*. Determine the static pressure, Mach number, and static temperature at the pipe inlet. (k = 1.4, R = *53.55)*

$$\frac{P_{t0}}{P_{s1}} = \left[1 + \frac{k-1}{2} M_1^2\right]^{\frac{k}{k-1}} \qquad 144pv = RT$$

$$\frac{T_{t0}}{T_{s1}} = 1 + \frac{k-1}{2} M_1^2 \qquad \dot{m} = \frac{Q}{v}$$

$$M = \frac{V}{\sqrt{kg_cRT}}$$

1. At standard conditions of 14.7 psia and 60°F,
$v = 53.35 \times (460 + 60)/(144 \times 14.7)$
$= 13.106\ ft^3/lb_m$

2. $Q = 1572/60 = 26.2$ std. ft^3/sec

3. $\dot{m} = 26.2/13.106 = 2.0\ lb_m/sec$

4. For this step only, assume the static temperature at the pipe inlet is equal to the reservoir temperature, then

$M_1 = 100.0/(1.4 \times 32.2 \times 53.35 \times 540)^{0.5}$
$= 0.0877$

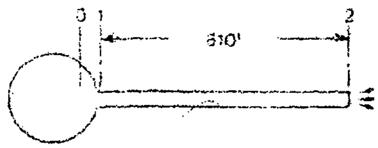
5. The total properties are constant across an isentropic process and

$T_{s1} = 540/[1.0 + (0.2 \times 0.0877^2)] = 539.17°R$

$p_{s1} = 114.7/[1.0 + (0.2 \times 0.0877^2)]^{3.5}$
$= 114.08$ psia

Step 4 can be recalculated using the temperature determined above; however, the difference is insignificant.

Problem 5



Size a compressed air header delivering air to a bank of air tools located 610 feet from the reservoir. The air [illegible] 100.0 psia. The reservoir is pressurized to 114.7 psia at 540°R. Losses due to fittings, valves, etc., are estimated to be 10% of the loss due to pipe friction. Determine the pipe size. Assume the process through the inlet nozzle, station 0 to 1, is isentropic. The flow process from station 1 to 2 is adiabatic with friction. (k = 1.4, R = 53.35)

$$M \cong 0.2245 \frac{\dot{m}}{d^2 p_t} \sqrt{\frac{RT_t}{k}}$$

$$\frac{P_{t0}}{P_{s1}} = \left[1 + \frac{k-1}{2} M_1^2\right]^{\frac{k}{k-1}} \qquad K = f\frac{L}{D}$$

1. For a static pressure loss in the order of 10% of the upstream pressure, the inlet Mach number will be approximately 0.075 to 0.10. Assume M_1 = 0.1.

2. The total properties are constant for an isentropic process. Calculate the pipe inside diameter using the approximate mass flow equation (see Problem 1).

$$0.10 = \frac{0.2245 \times 3.815}{d^2 \times 114.7} (53.35 \times 540/1.4)^{1/2}$$

d = 3.27 inches

3. From the pipe data in Appendix B and for schedule 40 pipe, read

3" nominal pipe size = 3.068 inches i.d.

4" nominal pipe size = 4.026 inches i.d.

(Although 3½" nominal pipe size is listed, this size is not used in industrial piping.)

4. Calculate the inlet Mach number for both of these pipes using the approximate isentropic mass flow equation (step 2).

For the 3" nominal pipe size, M_1 = 0.114

For the 4" nominal pipe size, M_1 = 0.066

5. Determine the pipe geometry coefficient. Assume f = 0.015.

For the 3" pipe,

K_{pipe} = 0.015 × 610 × 12/3.068 = 35.8

For the 4" pipe,

K_{pipe} = 0.015 × 610 × 12/4.026 = 27.27

For the 3" pipe,

[illegible]

For the 4" pipe,

K_{total} = 27.27 + 10% × 27.27 = 30.0

6. From Figure 4.15a, at M_1 = 0.114 and K = 39.4, read P_{s2}/P_{s1} = 0.53.

Obviously, the 3" pipe cannot meet the pressure requirement.

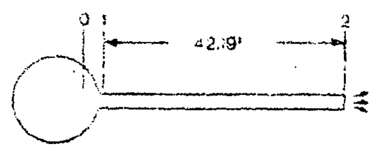
7. From Figure 4.15b, at M_1 = 0.066 and K = 30.0, read P_{s2}/P_{s1} = 0.904; the 4" pipe seems acceptable. The static pressure at the inlet can be calculated from

p_{s1} = 114.7/[1.0 + (0.2 × 0.066²)]^3.5 = 114.35 psia

p_{s2} = 0.904 × 114.35 = 103.37 psia which meets the required pressure at station 2.

8. The solution can be refined by determining the actual value of f and repeating step 5 through 9.

Problem 6



The reservoir contains air at 164.7 psia and 530°R and discharges through a schedule 40 steel vent line (i.d. = 2.067 in.) with a length of 42.19 feet. The pipe inlet is abrupt and the pipe contains 3-90 welding elbows. Calculate the flow rate and the inlet and outlet properties. Assume a Reynolds number of 1 × 10⁶ and a friction factor of 0.014. The flow process is isentropic from station 0 to 1 and adiabatic with friction from station 1 to 2. (K = 1.4, R = 53.35, μ_c = 0.0185).

$$M = 0.2245 \frac{\dot{m}}{d^2 p_t} \sqrt{\frac{RT_t}{k}} \qquad K = f\frac{L}{D}$$

$$M = \frac{V}{\sqrt{kg_c RT}} \qquad 144 p v = RT$$

$$\frac{P_{t0}}{P_{s1}} = \left[1 + \frac{k-1}{2} M_1^2\right]^{\frac{k}{k-1}} \qquad R_e = 124\frac{Vd\rho}{\mu_e}$$

$$\frac{T_{t0}}{T_s} = 1 + \frac{k-1}{2} M^2$$

1. Determine the pipe geometry coefficient.

   $K_{elbow} = 0.357;\ K_{inlet} = 0.5$

   $K_{pipe} = 0.014 \times 42.19 \times 12/2.067 = 3.429$

   $K_{total} = 3.429 + (3 \times 0.357) + 0.5 = 5.0$

2. This problem is unusual in that neither the flow rate nor the pressure drop is known. Assume $M_2 = 1.0$ at the pipe exit. Determine the "available static pressure loss" by assuming (for this step only) that the pipe inlet static pressure is the same as the reservoir pressure; then,

   $P_{s2}/P_{t1} = 14.7/164.7 = 0.089$ "available"

   From Figure 4.15a, $P_{s2}/P_{s1} = 0.089$ and $K = 5.0$ cannot be intersected and falls above the sonic line; thus, $M_2 = 1.0$. At $K = 5.0$ and $M_2 = 1.0$, read $P_{s2}/P_{s1} = 0.283$ and $M_1 = 0.307$.

3. The total properties are constant across the isentropic nozzle.

   $p_{s1} = 164.7/[1.0 + (0.2 \times 0.307^2)]^{3.5} = 154.3$ psia

4. $p_{s2} = 0.283 \times 154.3 = 43.67$ psia

   The excess static pressure at the pipe exit (43.67 − 14.7) will be dissipated outside of the pipe as shockwaves.

5. $T_{s1} = 530/[1.0 + (0.2 \times 0.307^2)] = 520.19°R$

6. The total temperature is constant across an adiabatic process; thus

   $T_{s2} = 530/[1.0 + (0.2 \times 1.0^2)] = 441.67°R$

7. The mass flow rate can be determined from the isentropic mass flow equation; however, since the static pressure and temperature at the pipe inlet, station 1, have already been determined, the mass flow equation will be used.

   $$0.307 = \frac{[illegible]}{2.067^2 \times 154.3}(53.35 \times 520.19/1.4)^{\cdot}$$

   $\dot{m} = 6.39\ lb_m/sec$

8. Determine the Reynolds number and friction factor at the pipe inlet.

   $V = 0.307 \times (1.4 \times 32.2 \times 53.35 \times 520.2)^{.5}$
   $= 343.39$ ft/s

   $\upsilon = 53.35 \times 520.2/(144 \times 154.3) = 1.249\ ft^3/lb_m$

   $\rho = 1.0/1.249 = 0.8006\ lb_m/ft^3$

   $R_e = 124.0 \times 343.39 \times 2.067 \times 0.8006/0.0185$
   $= 3.8 \times 10^6$

   $\epsilon = 0.00015$ ft (from Table 5.1)

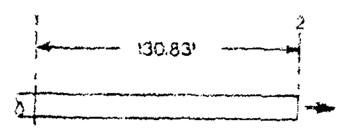
   $\epsilon/D = 0.00015 \times 12/2.067 = 0.00087$

   $f = 0.0190$ (from Figure 5.1)

   Using the new value of the friction factor, steps 1-8 may be repeated; however, the change in results will be insignificant.

9. Compare this solution with that determined in Problem 2. (Problem 2 has the same reservoir properties and the same nozzle diameter). By adding pipe to the nozzle, the flow rate was reduced by one-half. Adding additional pipe to the vent line will reduce the flow rate further and increase the loss in static pressure. At some new length, the static pressure at the pipe exit will be equal to the ambient pressure and the flow will be subsonic everywhere. Increasing the pipe length futher does not affect the exit pressure; however, the flow rate and velocity will decrease. (Recall, this problem concerns a constant area pipe. With changes in pipe area, $M = 1.0$ may exist within the piping system and the exit pressure still equal the ambient pressure).

Problem 7



A six inch safety relief valve mounted on a large manifold has a set pressure of 1214.7 psia and a flow capacity of 18.786 lb_m/sec. The manifold steam temperature is 1360°R. (The velocity in the manifold is negligible; thus, the manifold can be considered as a reservoir). The safety valve is connected to a six-inch (i.d. = 6.181 in.) vent stack, 130.83 feet in length. The back pressure during discharge should not be greater [illegible]

Determine the static pressure at station 1. The process is adiabatic with friction. ($k = 1.3$, $R = 85.14$, $f = 0.0157$)

$$M = 0.2245\frac{\dot{m}}{d^2 p_s}\sqrt{\frac{RT_s}{k}} \qquad K = f\frac{L}{D}$$

Galati, Anthony E

From: Sergi, Robert A
Sent: Tuesday, June 24, 2008 2:26 PM
To: Galati, Anthony E
Subject: FW: EDG air start Cranking times. (System Engr Input for EC-7135, EDG 31,32 and 33 Jacket Water Press Switch Mod)

Importance: High

From: Whitney, John C
Sent: Tuesday, June 24, 2008 2:20 PM
To: Sergi, Robert A
Subject: EDG air start Cranking times.

Bob: The average crank time for an EDG air start motor is 3 to 3.5 seconds.

R	ft-lbf/lbm °R	53.35		P_0	psia	188.8	*173.8 psig*	
k	dimensionless	1.4		T_0	°R	550		
d	in	1.61						
Q	SCFM	900		M1	dimensionless	***0.0763***		*<= "x" for initial guess*
v	ft^3/lbm	1.1		Right Side		0.0760		
mdot	lbm/sec	1.145		Left Side		0.0760		
				M1	dimensionless	0.0763		
$Q_{rec.charged}$	SCFM	700		M2	dimensionless	***0.0823***		*<= "x" for initial guess*
$Q_{rec.vented}$	SCFM	683.5		K	dimensionless	17.12		
				M2	dimensionless	0.0823		
		2.41%						
				P_{t1}	psia	188.8		
				P_{s1}	psia	188.0	*173.0 psig*	
				T_{t1}	°R	550		
				T_{s1}	°R	549.4		
				P_{s2}	psia	174.3	*159.3 psig*	
				T_{s2}	°R	549.3		
				M2	dimensionless	***0.0823***		*<= "x" for initial guess*
				Right Side		0.0824		
				Left Side		0.0824		
				M3	dimensionless	0.0823		
				M4	dimensionless	***0.1177***		*<= "x" for initial guess*
				K	dimensionless	53.22		
				M4	dimensionless	0.1177		
				P_{s3}	psia	121.8	*106.8 psig*	
				T_{s3}	°R	548.5		
				M3	dimensionless	***0.1177***		*<= "x" for initial guess*
				Right Side		0.1178		
				Left Side		0.1178		
				M3	dimensionless	0.1177		
				M4	dimensionless	***0.1435***		*<= "x" for initial guess*
				K	dimensionless	16.58		
				M4	dimensionless	0.1435		
				P_{s4}	psia	99.8	*84.8 psig*	
				T_{s4}	°R	547.7		

R	ft-lbf/lbm °R	53.35		P_0	psia	191.6	*176.6 psig*	
k	dimensionless	1.4		T_0	°R	550		
d	in	1.61						
Q	SCFM	900		M1	dimensionless	***0.0752***		*<= "x" for initial guess*
v	ft^3/lbm	1.1		Right Side		0.0749		
mdot	lbm/sec	1.145		Left Side		0.0749		
				M1	dimensionless	0.0752		
$Q_{rec.charged}$	SCFM	700		M2	dimensionless	***0.0809***		*<= "x" for initial guess*
$Q_{rec.vented}$	SCFM	683.5		K	dimensionless	17.12		
				M2	dimensionless	0.0809		
		2.41%						
				P_{t1}	psia	191.6		
				P_{s1}	psia	190.8	*175.8 psig*	
				T_{t1}	°R	550		
				T_{s1}	°R	549.4		
				P_{s2}	psia	177.3	*162.3 psig*	
				T_{s2}	°R	549.3		
				M2	dimensionless	***0.0809***		*<= "x" for initial guess*
				Right Side		0.0810		
				Left Side		0.0810		
				M3	dimensionless	0.0809		
				M4	dimensionless	***0.1136***		*<= "x" for initial guess*
				K	dimensionless	53.22		
				M4	dimensionless	0.1136		
				P_{s3}	psia	126.2	*111.2 psig*	
				T_{s3}	°R	548.6		
				M3	dimensionless	***0.1136***		*<= "x" for initial guess*
				Right Side		0.1138		
				Left Side		0.1138		
				M3	dimensionless	0.1136		
				M4	dimensionless	***0.1363***		*<= "x" for initial guess*
				K	dimensionless	16.58		
				M4	dimensionless	0.1363		
				P_{s4}	psia	105.1	*90.1 psig*	
				T_{s4}	°R	548.0		

Enclosure 2 To NL-09-119

Indian Point Unit 3 Calculation IP-CALC-07-00021, Rev. 1,

"Emergency Diesel Generator Starting Air System"

☐ ANO-1 ☐ ANO-2 ☐ GGNS ☐ IP-2 ☒ IP-3
☐ JAF ☐ PNPS ☐ RBS ☐ VY ☐ W3

CALCULATION COVER PAGE	**EC # 8648**	**Page 1 of 17**

Design Basis Calc. ☒ YES ☐ NO	☒ CALCULATION ☐ EC Markup
Calculation No: IP-CALC-07-00021	**Revision: 1**
Title: Emergency Diesel Generator Starting Air System	
System(s): EDG Starting Air	**Review Org (Department): DESIGN ENGINEERING - MECHANICAL**

Safety Class:	**Component/Equipment/Structure Type/Number:**	
☒ **Safety / Quality Related** ☐ **Augmented Quality Program** ☐ **Non-Safety Related**	EDG-31-SA-TNK	Air Start Motors
	EDG-32-SA-TNK	
	EDG-33-SA-TNK	
Document Type: Calculation		
Keywords (Description/Topical Codes): EDG, Starting Air, Starting Air Tanks and Overcrank Timer		

REVIEWS

Name/Signature/Date	Name/Signature/Date	Name/Signature/Date
[signature] 9/29/08 Anthony E. Galati **Responsible Engineer**	[signature] 9/29/08 Jerry P. Bubniak ☒ **Design Verifier** ☐ **Reviewer** ☐ Comments Attached	[signature] 9/30/08 **Supervisor/Approval** ☐ Comments Attached

CALCULATION REFERENCE SHEET	CALCULATION NO: IP-CALC-07-00021 REVISION: 1

I. EC Markups Incorporated

1.
2.
3.
4.
5.

II. Relationships:	Sht	Rev	Input Doc	Output Doc	Impact Y/N	Tracking No.
1.			☐	☐		
2.			☐	☐		
3.			☐	☐		
4.			☐	☐		
5.			☐	☐		

III. CROSS REFERENCES:

1.
2.
3.
4.
5.

IV. SOFTWARE USED: None

Title: Version/Release: Disk/CD No. NA

V. DISK/CDS INCLUDED:

Title:_________________ Version/Release_________Disk/CD No.______

VI. OTHER CHANGES:

RECORD OF REVISIONS

Calculation Number: IP-CALC-07-00021 Page 3 of 17

Revision No.	Description of Change	Reason For Change
0	Initial Issue	Initial Issue
1	Revised pages 5 & 17 Changes are in bold type	Scope of EC7135 was revised to delete the replacement of jacket water pressure switches JWPS-1, 2 and low pressure alarm setpont changes. New EC 8648 was prepared for jacket water pressure switch replacement and setpoint changes.

TABLE OF CONTENTS

Attachments

Background

The diesel generator starting air system (DA) provides sufficient compressed air to start (crank) the diesel engines. During emergency operation, starting air is supplied from the starting air tank to the air motors, which in turn crank the engine. There are two air motors per engine, each capable of starting the diesel in the allotted time. The starting air compressor can replenish the air in the starting air tank; however, the starting air compressor is not a safety related component and its function can not be credited in maintaining air tank pressure.

The existing air start motors are vane type Ingersoll-Rand model ST950BIO33R31.The original air start motors were also manufactured by Ingersoll-Rand and were replaced by DCP-97-3-058 in 2001.

This calculation is being performed to address concerns raised in CRs IP3-2006-04063 and IP2-2006-07329 and support **EC 8648 "Replacement of EDG 31, 32 and 33 Jacket Water Pressure Switches JWPS-1 and 2 and Set Point Changes. Also, Change Starting Air Receiver Low Pressure Alarm Set Point"**

Purpose

The purpose of this calculation is to determine the number of normal diesel starts available from the starting air tank (Starting Air Tank No. 31, 32, or 33) without the assistance of air from the starting air compressor. The calculation will determine the system pressure drop between the air receiver and the air start motors in order to establish the minimum air receiver pressure required for a normal start.

This calculation will also evaluate the present overcrank timer setting for the diesel starting air system.

Conclusion

This calculation demonstrates that the starting air tank can provide three (3) air starts without assistance from the starting air compressors. The pressure in the air receiver after the third start is 168 psia (153 psig).

The minimum pressure in the air receiver tank required to deliver 800 scfm of air at 90 psig to the inlet of the air start motors is 187 psig.

The overcrank timer setting which is presently set at 15 seconds should remain unchanged. After engine lockout and shutdown the starting air tank will not have enough air for a start.

Input & Design Criteria

1. Air start motor flow rate is 800 scfm at 90 psig, Reference 17.
2. A minimum pressure of 90 psig at the air motor is required for reliable starts, Reference 2.
3. The present internal volume of the starting air tank is 49.3 ft^3 per calculation IP-CALC-08-00068 (Reference 18). A future proposed modification which will modify the tank and apply an internal protective coating will increase the internal volume to 49.7 ft^3. A conservative internal volume of 49 ft^3 will be used for this calculation.
4. Piping arrangements for the starting air system are shown on References 5 and 6.
5. Starting air tank pressure alarm is set at 255 psig, which is a minimum of 20 psi lower than the normal tank pressure range maintained by the stating air system compressors, Reference 19.
6. Room and tank ambient air temperature of 90^0 F will be used for this calculation.

Assumptions
Based on information provided in Reference 20, an average crank time of 4 seconds will be assumed.

Method of Analysis

All equations for this analysis with respect to air flow are from the Compressible Flow Manual, Reference 1.

This calculation will use the manufacturer's air motor consumption data and an average crank time of four (4) seconds to determine the number of air starts available from the start air tank. This calculation will also determine pressure drop from the starting air tank to the air motor. This pressure drop will be used to determine the minimum starting air tank pressure required to ensure a minimum 90 psig can be supplied to the air start motor.

Calculation/Analysis

This calculation will determine the final pressure in the starting air tank after three (3) normal diesel starts without the assistance of air from the starting air compressor and determine the system pressure drop between the starting air tank and the air start motors.

Starting Air Motor Consumption

DCP 97-3-058 states that the air consumption is 800 scfm at 90 psig.
Older catalog data for the air start motors, pre-dating the above referenced design change, states air consumption as 700 scfm at 90 psig.
Newer catalog data states air consumption as 850 scfm at 90 psig.

An air consumption value of 800 scfm will be used for the air start motors in this calculation.

Starting Air Tank Pressure

From Reference 4, the air pressure in the starting air tanks is normally maintained between 275 psig and 300 psig. However, the low pressure alarm setting is 255 psig (270 psia) per Reference 19 and this pressure will be used as a conservative starting pressure for this calculation. At this pressure, the mass of air in each starting air tank is calculated as follows:

$$m = \frac{144pV}{RT}$$

Where:

m = mass (lbm)
p = pressure (psia)
V = volume (ft^3)
R = Specific gas constant for air (53.35 ft-lbf/lbm °R) Ref. 1
T = Temperature (°R)

Using room temperature for air (90°F or 550°R) and a pressure of 255 psig (270 psia), the initial mass in the starting air tank is:

$$m = \frac{144pV}{RT} = \frac{144(270)(49)}{(53.35)(550)} = 64.9\ lbm$$

The air consumption of each air start motor is 800 scfm. This flow rate will be used to determine the mass of air remaining in the tank after three (3) consecutive starts.

It is assumed that an average start will occur within approximately 4 seconds. Therefore, the mass of air evacuated during this period is as follows:

$$\dot{m} = 0.06787 \frac{(SCFM)}{R}$$ Ref. 1

Where:

$\dot{m}$ = mass flow rate (lbm/sec)
SCFM = Flow rate in standard cubic feet per minute (14.7 psia and 60°F)
R = Specific gas constant for air (53.35 ft-lbf/lbm °R)

Using flow rate of 2 x 800 SCFM (required flow for both air starters), the mass flow from each starting air tank is:

$$\dot{m} = 0.06787 \frac{SCFM}{R} = 0.06787 \frac{(1600)}{53.35} = 2.035 \text{ lbm/sec}$$

Therefore, the amount of air removed from the starting air tank after some time, t, will be:

$$m_{final} = m_{initial} - \dot{m}t$$

After three (3) starts (12 seconds), the mass of air remaining in the starting air tank will be:

$$m_{final} = m_{initial} - m_t = 64.9 - 2.035(12) = 40.5 \text{ lbm}$$

The pressure in the starting air tank at this point will be:

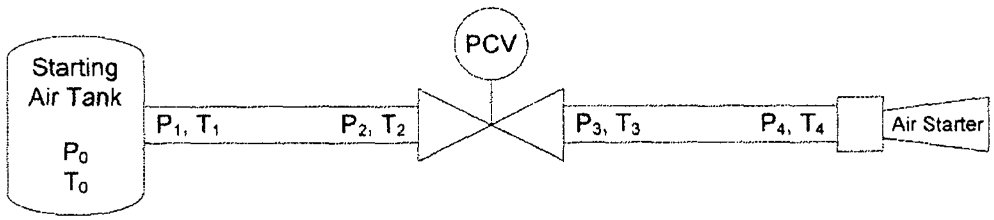
$$p = \frac{mRT}{144V} = \frac{40.5(53.35)(550)}{144(49)} = 168.4\ psia$$

Pressure drop from starting air tank to pressure control valve

Air pressure to each starting motor is regulated by a pressure control valve (PCV-14-1 through PCV-14-6). From Reference 4, these pressure reducing valves regulate downstream pressure to 135 ± 15 psig.

Piping from the starting air tank to these valves is depicted on References 5 and 6. As shown on the above referenced drawings the piping has a nominal pipe size of 1-1/2 inches. The piping is schedule 80 stainless steel (Reference 7 and 15).

After a review of all six piping runs, the following represents the most conservative configuration from a hydraulic resistance standpoint. Unless otherwise noted, fitting resistances are based on Crane Technical Paper No. 410.



Turbulent Friction Factor			
f_t	0.020537	(Re = ∞, ε = 0.00015)	Colebrook Equation
Piping			
L (ft)	46		
D (in)	1.5		
Pipe K	**7.56**	$=f_t * 12 L / d$	
Fittings			
1 x Entrance, Sharp Edged, Flush (K = 0.5)	0.5		
9x Standard Elbow, 90° ($K = 30f_t$)	5.54	$=QTY * 30 * f_t$	
1 x 300 mesh Strainer (Cv = 65)	1.07	$=890\ d^4 / C_v^2$	Reference 7: Ingersoll Rand Model ST900-267-24 strainer Reference 11: Cash Acme Strainer Bulletin
Fitting K	**7.11**		
Valves (DA-9, 10 & 11)			
1 x Gate Valve: $K = 8f_t$ (Cv = 165)	0.17	$=890\ d^4 / C_v^2$	Reference 10: Crane Technical Paper No. 410
Valve K	**0.17**		
K Total	**14.84**		

Based on this hydraulic resistance, the pressure drop from the starting air tank to the pressure control valve is as follows:

In the tank, total properties equal static properties ($P_{t0} = P_{s0}$, $T_{t0} = T_{s0}$). Flow from the tank to the piping is taken as isentropic. Therefore, the total properties are constant:

$P_{t0} = P_{t1} = 168.4$ psia
$T_{t0} = T_{t1} = 550$ °R

The Mach Number at station 1 (M_1) is found as follows:

$$M\left[1+\frac{k-1}{2}M^2\right]^{-\frac{k+1}{2(k-1)}} = 0.2245\frac{\dot{m}}{d^2P_t}\sqrt{\frac{RT_t}{k}}$$ Ref. 1

Where:
- M = Mach number (dimensionless)
- k = Isentropic Exponent for air (1.4)
- $\dot{m}$ = mass flow rate (lbm/sec)
- d = inside pipe diameter (in)
- P_t = Total Pressure (psia)
- T_t = Total Temperature (°R)
- R = Specific gas constant for air (53.35 ft-lbf/lbm °R)

Based on a volumetric flow rate of 800 SCFM, the mass flow rate is:

$$\dot{m} = 0.06787\frac{(SCFM)}{R} = 0.06787\frac{(800)}{53.35} = 1.018 \text{ lbm/sec}$$

Assuming a Mach number of 0.0877 yields the following:

$$M\left[1+\frac{k-1}{2}M^2\right]^{-\frac{k+1}{2(k-1)}} = 0.2245\frac{\dot{m}}{d^2P_t}\sqrt{\frac{RT_t}{k}}$$

$$0.0877\left[1+\frac{1.4-1}{2}0.0877^2\right]^{-\frac{1.4+1}{2(1.4-1)}} = 0.2245\frac{1.018}{1.5^2(168.4)}\sqrt{\frac{53.35(550)}{1.4}}$$

$$0.0877 = 0.0877$$

Therefore the assumption for M_1 of 0.0877 is correct.

The Mach number at station 2 (M_2) is found as follows:

$$K = \frac{1}{kM_1^2} - \frac{1}{kM_2^2} + \frac{k+1}{2k}\ln\frac{M_1^2\left[2+(k-1)M_2^2\right]}{M_2^2\left[2+(k-1)M_1^2\right]}$$ Ref. 1

Where:
- K = Loss Coefficient (dimensionless)

Assuming a Mach number at station 2 of 0.0958 yields the following:

$$14.84 = \frac{1}{1.4(0.0877)^2} - \frac{1}{1.4(0.0958)^2} + \frac{1.4+1}{2(1.4)} \ln \frac{(0.0877)^2}{(0.0958)^2} \left[\frac{2+(1.4-1)(0.0958)^2}{2+(1.4-1)(0.0877)^2} \right]$$

$$14.84 = 14.84$$

Therefore the assumption for M_2 of 0.0958 is correct.

With these Mach Numbers, static pressures at stations 1 and 2 can be found:

$$\frac{P_t}{P_s} = \left[1 + \frac{k-1}{2} M_2^2 \right]^{\frac{k}{k-1}}$$ Ref. 1

Therefore P_{s1} is:

$$P_{s1} = P_{t1} \Big/ \left[1 + \frac{k-1}{2} M_2^2 \right]^{\frac{k}{k-1}} = 168.4 \Big/ \left[1 + \frac{1.4-1}{2} (0.0958)^2 \right]^{\frac{1.4}{1.4-1}} = 167.5 \; psia$$

And P_{s2} is found as follows:

$$\frac{P_{s2}}{P_{s1}} = \frac{M_1}{M_2} \sqrt{\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}}$$ Ref. 1

$$P_{s2} = P_{s1} \frac{M_1}{M_2} \sqrt{\frac{2+(k-1)M_1^2}{2+(k-1)M_2^2}} = 167.5 \frac{0.0877}{0.0958} \sqrt{\frac{2+(1.4-1)0.0877^2}{2+(1.4-1)0.0958^2}} = 153.4 \; psia = 138.4 \; psig$$

Pressure drop across pressure control valve

As shown above, the downstream pressure is approximately equal to the valve set pressure. Therefore the valve will be assumed to be full open. From Reference 13, the full open flow coefficient of this valve is 14.6.

Turbulent Friction Factor			
f_t	0.020537	(Re = ∞, ε = 0.00015)	Colebrook Equation
Piping			
L (ft)	0		
D (in)	1.5		
Pipe K	**0.00**	$= f_t * 12\ L / d$	
Valves			
1 x Pressure Control Valve (C_v = 14.6) DA-PCV-14	21.14	$= 890\ d^4 \div C_v^2$	Reference 13: Cash Acme 'B' Series Pressure Regulator Valve
Valve K	**21.14**		
K Total	**21.14**		

The Mach number at station 3 (M_3) is found as follows:

$$K = \frac{1}{kM_2^2} - \frac{1}{kM_3^2} + \frac{k+1}{2k}\ln\frac{M_2^2\left[2+(k-1)M_3^2\right]}{M_3^2\left[2+(k-1)M_2^2\right]}$$

Where:
K = Loss Coefficient (dimensionless)

Assuming a Mach number at station 3 of 0.1125 yields the following:

$$21.14 = \frac{1}{1.4(0.0958)^2} - \frac{1}{1.4(0.1125)^2} + \frac{1.4+1}{2(1.4)}\ln\frac{(0.0958)^2\left[2+(1.4-1)(0.1125)^2\right]}{(0.1125)^2\left[2+(1.4-1)(0.0958)^2\right]}$$
$$21.14 = 21.14$$

Therefore the assumption for M_3 of 0.1125 is correct.

With these Mach Numbers, static pressure at station 3, P_{s3}, can be found as follows:

$$\frac{P_{s3}}{P_{s2}} = \frac{M_2}{M_3}\sqrt{\frac{2+(k-1)M_2^2}{2+(k-1)M_3^2}}$$

$$P_{s3} = P_{s2}\frac{M_2}{M_3}\sqrt{\frac{2+(k-1)M_2^2}{2+(k-1)M_3^2}} = 153.4\frac{0.0958}{0.1125}\sqrt{\frac{2+(1.4-1)0.0958^2}{2+(1.4-1)0.1125^2}} = 130.5\ psia = 115.5\ psig$$

Pressure drop from pressure control valve to air motor

Piping configuration from the pressure control valve to the air motor was determined based on field walkdown. As stated in Reference 7, the piping has a nominal pipe size of 1-1/2 inches and is schedule 80 stainless steel.

Based on a review of all the six piping runs, the following represents the most conservative configuration from a hydraulic resistance standpoint. Unless otherwise noted, fitting resistances are based on Reference 10:

Turbulent Friction Factor			
f_t	0.020537	($Re = \infty$, $\varepsilon = 0.00015$)	Colebrook Equation
Piping			
L (ft)	1		
D (in)	1.5		
Pipe K	**0.16**	$=f_t * 12 L / d$	
Fittings			
4x Standard Elbow, 90° ($K = 30f_t$)	2.46	$=QTY * 30 * f_t$	
Fitting K	**2.46**		
Valves			
1 x Solenoid Valve (Cv = 29)	5.36	$=890\ d^4 / C_v^2$	Reference 8 Ross Controls Model 2671A8011 valve
1 x Stop Valves ($K = 340f_t$)	6.98	$= QTY * 340 * f_t$	Reference 16 Crane Figure 1 (1 ½" globe valve)
Valve K	**12.34**		
K Total	**14.96**		

The Mach Number at station 4 (M_4) is found as follows:

$$K = \frac{1}{kM_3^2} - \frac{1}{kM_4^2} + \frac{k+1}{2k} \ln \frac{M_3^2\left[2+(k-1)M_4^2\right]}{M_4^2\left[2+(k-1)M_3^2\right]}$$

Assuming a Mach Number at station 4 of 0.1316 yields the following:

$$14.96 = \frac{1}{1.4(0.1125)^2} - \frac{1}{1.4(0.1316)^2} + \frac{1.4+1}{2(1.4)} \ln \frac{(0.1125)^2\left[2+(1.4-1)(0.1316)^2\right]}{(0.1316)^2\left[2+(1.4-1)(0.1125)^2\right]}$$
$$14.96 = 14.96$$

Therefore the assumption for M_4 of 0.1316 is correct.

With these Mach Numbers, static pressures at station 4 can be found:

$$\frac{P_t}{P_s} = \left[1 + \frac{k-1}{2} M^2\right]^{\frac{k}{k-1}}$$

And P_{s4} is found as follows:

$$\frac{P_{s4}}{P_{s3}} = \frac{M_3}{M_4}\sqrt{\frac{2+(k-1)M_3^2}{2+(k-1)M_4^2}}$$

$$P_{s4} = P_{s3}\frac{M_3}{M_4}\sqrt{\frac{2+(k-1)M_3^2}{2+(k-1)M_4^2}} = 130.5\frac{0.1125}{0.1316}\sqrt{\frac{2+(1.4-1)0.1125^2}{2+(1.4-1)0.1316^2}} = 111.5\ psia = 96.5\ psig$$

Overcrank Timer Analysis

The purpose of this section of the calculation is to evaluate the overcrank timer setting.

The air starting system is designed to shutdown and lockout any engine which does not start during the initial start attempt. Failure of the engine to start within the timing period of the overcrank time indicates a malfunction and based on the current design philosophy, the overcrank timer setting should conserve enough air mass in the starting air tank for one more start attempt.

The existing overcrank relays has a set point of 15 seconds. The minimum pressure in the air receiver tank required to deliver 800 scfm of air at 90 psig to the inlet of the air start motors is 187 psig. Since this is the tank pressure after the second 4 second start, the overcrank timer setting would need to be change to 8 seconds to ensure that enough air is available for one more start attempt. However, lowering the overcrank relay setting to 8 seconds may place it too close to the assumed normal start time of 4 seconds and may prematurely shutdown and lockout the engine during a normal start when no malfunctions exist. Therefore, the overcrank timer setting should not be changed.

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19. **EC 8648 "Replacement of EDG 31, 32 and 33 Jacket Water Pressure Switches JWPS-1 and 2 and Set Point Changes. Also, Change Starting Air Receiver Low Pressure Alarm Set Point"**
20. E-mail dated 6/24/08 from J. Whitney to R. Sergi