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TEXAS A AND M UNIV COLLEGE STATION  
CRUDE OIL LOSSES AND POLLUTION, TANKER INERTING AND CLEANING, H--ETC(U)  
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of the proposed system. Follow on research must eventually test and evaluate these assumptions (Chapanis, 1972).

#### System Feasibility

Enough proof now exists for at least continued research on this system. There appears to be no legitimate reason to continue subjecting personnel, equipment, ships/vehicles, stationary tanks, and cargo to the hazards associated with the techniques discussed in prior sections for tank inerting and cleaning. With today's technology there is no justification for human entry into tanks, other than for tank repair and/or modification. Human error is a function of stress, other things being equal, and in-tank work is stressful.

Even using bag techniques (Carmichael, 1972), the cleaning operation must either use a bag for the cargo and a bag-well for the cargo-pushing fluid or a well for the cargo and a bag for the cargo-pushing fluid. Neither of these bag techniques is particularly appealing since contamination is still present in either the well, the bag, or both, especially due to the constant flexing and the corrosive nature of the action that takes place across the bag membrane. For either of these bag techniques, however, the addition of another fluid-entry port is still a requirement and an additional cargo-pushing fluid is also necessary. With the proposed Freon system, no bag is required, the attendant corrosion is eliminated, the entire tank is purged and cleaned, and removal of the cargo-pushing fluid occurs along with removal of the cargo.

In summary, using this system, all of the steps--from tie-up to untying--should be fast, efficient, safe, nontoxic, and non-polluting. The systematic procedures make use of modern technology and are compatible with projected tanker designs and an ecologically sensitive citizenry (EPA, 1971; 1972). Previously-lost cleaning materials and cargo are recovered apparently and significantly increasing a tanker's per-voyage cargo capacity. Much of the previously required on-board inerting and cleaning equipment may be removed from the tanker. Equipment space and slop-tankage should be liberated for active cargo or ballast use, once authorities agree to the changes in oily-waste containment requirements. These factors should help to offset the proposed capital expenditure ultimately sustained by the carrier while the improvement in safety and clean-up activities should satisfy the most fiscally-cautious port authorities. It is anticipated that loading and unloading times will also be reduced by the system.

If the next cargo is located at the discharge port, with full-time tank usage, the tanker does not require the usual ballasting between ports nor does it support the practice of off-shore oily-waste dumping. With the proposed system, the tanker does not sustain the usual downtime needed for ventilation or gas-free certification. It can therefore be on-line (in service) much more rapidly giving it more duty-days per year. Once inerted with vaporous Freon and if located with the next compatible cargo so that no cleaning is required, loading can use both sets of lines (input and output

lines) to almost double loading speed while venting the Freon out through the deck hatches. These hatches would be covered with vapor recovery units to reclaim the exiting vaporous Freon.

With the proposed system, like loading, unloading can be significantly faster than before. Any standard hatch can be used for entry of the Bristol or Butterworth type machines through which to inject vaporous Freon to fill the void as detailed in prior sections. In fact, unloading can be hastened further by the maintenance of a slight positive pressure or head with the Freon via shore-side pumps, which was not possible when the tanker was open to and contaminating the atmosphere. Although the hastening mentioned above is insignificant by itself, the slight pressure that is possible with the proposed closed-loop system facilitates monitoring and control functions that would not work with an open system. Specific procedures are suggested in Appendix-B, as a guide.

Using the same basic system concept, various alternatives are possible. These alternatives, can be based upon traffic or fiscal factors, and can be tailored to a given port environment. Where real estate costs are not significant, the extra Freon storage suggested in the prior chapter, "Recommended Field Installation" (p. 64), may be the ideal approach. This approach would allow a smaller, slower and less-costly separation function that could be off-line. Where real estate costs are of prime concern, a larger serial, on-line separation function would allow the same reaction time with a smaller quantity of Freon.

If the next cargo is not located at the port of discharge, then a given tanker will still be on line much more rapidly than before because of faster discharge of its first cargo, and faster inerting. Inerting with the proposed system begins while the tank is above the UEL and continues through cleaning at below the LEL. The in-rush of inerting material aids evacuation of the cargo since a closed system is used permitting a slight head or pressure to help force the activity through completion. During this entire procedure, no oxygen-rich air or humans will be admitted into the tank. Now, the ship may embark to pick up its next cargo with inerted and cleaned tanks. Vaporous or liquid Freon remaining in the tanks will continue to protect these tanks right up to and including the loading of the next cargo, at the ship's next port of call. Similar to the prior procedure for loading, vapor recovery units capture the remaining Freon while loading the next cargo. Loading speed is almost doubled, no air is introduced, the system remains for all intentions closed, and no new hazards are introduced as the tanks go from below the LEL back up to their full level above the UEL. Ventilation, required only for in-tank inspection, maintenance, or modification, can be achieved as before but, because of Freon's low level of toxicity and excellent flash-point retardation, with less risk to the crews doing such work (Gafafer, 1964).

Thus, operators may achieve reduced costs, as follows. An increased loaded utilization rate with no change in maintenance expenses can be achieved as well as a reduction of ballasted travel

for cleaning between uses. Expense may be further reduced since the Freon inerting/cleaning material is recovered. Where both labor and cleaning materials were expended before, now only in-port cleaning labor is sustained. With the proposed system's attendant hazard reduction, insurance premiums should also be reduced as various proofs of system validity are accumulated. Now, with waterless cleaning, the possibility of waterless ballast runs between cargo-1 discharge and cargo-2 loading if not colocated, are possible and rusting can be reduced. By this means, ship integrity may be improved and human lives may be saved (U. S. Department of the Navy, 1971).

#### The Need for Follow-Up Research

Much more research must be completed to clearly identify all of the costs, as well as the savings, that will accrue. The system will obviously be expensive due to the equipment and off-shore or port-side real estate alone. Furthermore at current rates of approximately 35¢/pound, Freon-TF is expensive and only available from a few sources. Since no other known system or user employs Freon quantities approaching these requirements, there may be room for price negotiations.

Follow-up research should also attempt to get universal adoption of the system. Ultimately, standardization and implementation of the system will have to be promulgated by a multi-national body such as the Inter-Governmental Maritime Consultative Organization to provide the required safety at all ports. It would not be

reasonable to be safe at Port-A only to re-expose the ship, crew and cargo to undo hazards at Port-B. Also, in light of its costs, certain Freon or Freon-imposed losses that could be discovered later as inherent to the system and its components will have to be faced and quantified.

Follow-up research will have to solve the problem of Freon not being compatible with certain cargos, coatings, or materials such as silicon elastomers, polystyrene plastics, or zinc (DuPont, 1972c).

A saving that will have to be shown and is not yet quantified satisfactorily is the total value of recovered oil associated with bilge, ballast and deep tank cleaning operations. There is a documented annual loss of one-billion gallons (or 4.5 million tons) in the Houston Gulf Coast area alone (F. R. Harris, 1972). Furthermore, the bilge and ballast operations are not limited to chemical, oil, and LPG tankers, but applicable to OBO's and dry-bulk freighters as well. Once quantified, it is anticipated that the resulting saving will aid in offsetting the cost of processing the Freon as well as many other costs.

Continued research should uncover methods to broaden the system's application and extend usefulness to the various commodities listed in the latest issue of Table 30.25-1 of the Code of Federal Regulations (CFR)-46 "SHIPPING" (General Services Administration, 1972). This effort should be objective enough to determine whether optimum results can best be obtained by a change of procedures involved specifically with the commodities listed, by modification

of this system, or a combination of the two.

It is important to evaluate possible efficiencies that the system might provide in solving the empty-return dead-heading runs\* and other tanker or non-tanker cargo, process, waste-treatment, or handling problems. It is also conceivable that the system could have merit when applied to other industrial problem areas; e.g., cold rolling steel process (U. S. DOI, 1970). These efficiencies may be achieved from such applications by slight modification of the system or by one of the three changes noted in the preceding paragraph.

Lastly, it might be lucrative to evaluate possible efficiencies that might accrue from an accumulation of components from industries that currently supply quality hardware, software or services and that are based in cooperating countries such as those participating through the Safety Of Life At Sea conventions. Perhaps optimized components via improved maintainability, reliability, and/or logistics may be obtainable at no additional expense. In this way, universal appeal may be served by the sharing of not only costs, but also technology. There may be greater participation if the maximum number of participants in the tanker loop have a stake in the ultimate design and are given a chance at the new industrial economic growth that the system is capable of providing.

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\*Rapidly cleaned ships may be able to serve transportation in new ways not yet imagined, once they are made available. If only to exclude the water ballast and attending corrosion problems, progress will have been achieved.

### Recovery of Contact-Surface and Ullage Vapor Losses

Using Load On Top (LOT) a certain amount of the Freon vapor will be picked up by fresh incoming cargo. Now, if the bulk of the Freon remains in its vaporous state, it will tend to inert the ullage space above the cargo and retain the subject tank in a safe, reduced air or oxygen starved condition. Any free liquid Freon present will sink to the bottom of the tank. This effect is not without merit since the Freon will then tend to keep the tank bottom clean and corrosion-free by reducing sludge formation. A barrier will minimize Freon/crude contamination.

Freon/crude action in a simulated or real-world tanker environment will have to be evaluated further. It seems reasonable to assume that in some cases a finite amount of Freon vapor will remain above the crude. The question in this case is whether the remaining amount will be sufficient to act as an inerting blanket. It also seems reasonable to assume that in other extreme cases a certain amount of liquid Freon will contaminate the crude even via contact surfaces. The question here is whether this contamination is sufficient to require extensive volumes of cargo distillation to reduce the Freon concentration ahead of the refinery process, as discussed in the next subsection.

It is possible for normal ship motion to elevate internal tank temperature above the Freon atmospheric boiling point (118°F) thus helping any free Freon present to remain vaporous (DuPont, 1970). Tests must be performed to identify the amount and rate of occlusion

that takes place as discussed immediately above. The relationship that may exist between occlusion and saturation should also be experimentally determined. During this recommended phase of testing, it will be interesting to note the degree of cooling (if any) that takes place in the tank (see "Test Tank," pg. 39) resulting from any outgassing of the Freon through pressure relief valves and what effect this cooling has.

Because of the relatively high cost of the Freon vapor, recovery units are recommended and assumed in all prior discussions of cargo loading and unloading. These units will capture the exiting Freon enabling a more complete recycle and assuring atmospheric protection. Infra-red techniques employing LIRA-type equipment (MSA, 1972) should be used to allow later visual observation of the Freon in the various simulated crude-oil/tank environments. These techniques will also allow observation of action along the Freon/air interface.

#### Possible Catalyst Losses in Refining the Crude

If trace amounts of Freon remain occluded within the crude and if the distillation process is used to separate the Freon/crude mixture, it is imperative for this distillation process to be highly efficient. If not sufficiently effective, or if this distillation is not port-shared by all of the contributing refineries as an initial refinery process, any Freon remaining in the crude after distillation can be adverse to further refinery operations. This is due to the chemical contamination of the platinum catalyst by Freon

at elevated crude-oil refinery temperatures. This contamination may impose some new, burdensome repair costs upon the refineries if not properly addressed.

#### Detail Design Factors

Detail design factors remain to be worked out prior to initiation of a model installation. Typical of these are the additional testing and tradeoffs that will have to be accomplished to answer such questions as (U. S. Department of the Air Force, 1965):

1. Optimum line length, if not dictated by other physical constraints, to minimize sampling reaction-time to faults or tolerance limits.
2. What elements, if any, should have internal power supplies to minimize case penetrations, while accepting a certain degree of calibration and corrosion difficulty.
3. Where to locate the Freon line heater for maximum safety, to inject vaporous Freon during inerting.
4. Optimum Freon input rate for inerting/cleaning versus static build-up.

#### The Need for a Forum and System Exposure

The program should be expanded to at least point the prospective system users and legislators toward the need for:

1. An understanding of and familiarity with the true value of this waterless system in relation to its cost.

2. Using continuous monitoring by qualified personnel. Most operators are already using certified-safe equipment, and following approved procedures within a somewhat approved/controlled environment. This step can effectively be accomplished by employing U. S. aerospace techniques such as the nine design steps per paragraph 5.4.1 of MIL-STD-882 (U. S. DoD, 1969). Tank cleaning monitors and operators should be properly trained and certified in a manner similar to AFIC AFM 127-100 per 30ZRR4625X as defined by the U. S. Air Force Directorate of Safety (U. S. Dept. of the Air Force, 1973d).
3. Getting a uniform/standard approach to the problem and its solution to save:
  - a) Personnel turnover, accidents, and life expectancy
  - b) Personnel training costs
  - c) Port-side facilities and real estate
  - d) Ship and equipment down-time
  - e) Cargo while increasing per-voyage yield
  - f) Inerting and cleaning material
  - g) The natural ecology.

A bi-directional interchange of data should expedite solutions to the various problems listed above and may also act to accelerate acceptance of the proposed system.

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## APPENDIX-A

## Glossary of Research-Related Terms

Using the EPA "Microthesaurus of Air Pollution Terms" as a guide, a list is provided below to identify key areas of interest based upon the problem and the proposed system (solution).

abatement	behavior
abrasion reduction	bilges
accident prevention	Blaco-tron (Baron-Blakeslee)
adaptable	blanketing cargo
additional safety features added	blowers eliminated
advance warning	$C_2Cl_3F_3$
airborne tankers	$CF_3Br$
ambient environment	cargo loss/handling
analysis	cargo transfer
anxiety reduced	catastrophic damage
attributes	centralized operation
architectural work space layout	certification of facility and personnel
audible feedback	chemical certification
auto-ignition	classification
automation	cleaning agent recovery
auxilliary safety function	cleanliness improvement
ballast	closed-loop operation
	cofferdams

cold process	dielectric strength of Freon
colorimetry	display quickening
compatibility	distillation
comingling of products	dropping
compensation	dry dock use reduced
computer support	duration of exposure
connect-disconnect times unchanged	duty-cycle capable of being increased
conservation of manpower	ecological principles
contamination (cargo/ cleaning agent)	economic growth
continuous sampling included	efficiency enhancement
control (automatic/ manual)	electrical hazards
control aiding	electrolysis
cooling	elevated temperature
corrosive action	empirical results
cost reduction/bene- fit/effectiveness	emulsion action
critical incidents	energy conservation
critical temperature	engine room
crude oil	engineering
degradation	equipment utilization
design simplicity	error
detectors	estuaries
	evaluation
	evidence/support

experiments and tests	halogenated hydrocarbon
explosion protection/ proofing	Halon
exposure (environmental/ military)	harbor
facilities	hardware
facility design	hazards identified and controlled
fail safe features	heightened availability
falling	hot process
federal, state, and local regulation and support	human factors engineering
fire protection/proofing	human stress reduced
fixed tanks (tank farms)	human work load reduced
flammability range	IMCO
flash point suppression	identification of hazards
flow rate increased	industrial growth and support
fluorinated hydrocarbon	inert material
formula	inerting agent recovery
Freon	infra-red detection
galvanic corrosion reduced	inherent safety
gas freeing	in-port functions expanded
Gascope	installation ease
geographic location adaptability	instrumentation
growth potential provided	insulation resistance
halide meter	insurance costs minimized
	in-tank entry eliminated

integrated	maximum up-time and feedback
interlocked for safety	
International Maritime Con- sultative Organization	minimum down-time
invasion of O <sub>2</sub> -laden air	minimum waste
isolation of products	miscibility
Kuwait Crude	mission profile
LEL	mixing rate
LOT	mobile
leak detection	modifications
leaking	minimized
liberated on-board space	Modified Load On Top
life expectancy lengthened	modular
lightning protection	monitoring improved (automatic/manual)
liquid products	monobromotrifluoromethane
liquifaction	mucking
litigation reduction	multi-point (grid) sampling
Load On Top	new process-plant requirement
logistics	new products
longevity	OBO
lower explosive limit	observation
MIUS	off-tank inert-gas generation
MOD	off-the-shelf hardware
manual functions reduced	oil

oily-waste	precision
operations research	prediction of traffic
optimum configuration	pressure
other agents (inerting or cleaning)	procedurally streamlined
out gas (evolve)	procedures
overpressure limit	programmable processing
oxidation minimized	projected growth and importance
oxygen analyzer	pumps
oxygen content	purging
oxygen starvation	purity/quality enhancement
parallel operation	push-pull operation
Pensky-Martens	rail head installation
periodic maintenance (ship/tank) simplified	rapid results
personnel selection and retention improved	re-cycle
physical hazards	remote monitoring
pipng systems	response time
planning	restriction of environment
plant life	results (immediate)
pollution reduced (air/ water)	risk classification
port usage increased (traffic volume)	SOLAS
positive pressure	Safety Of Life At Sea
pourability	safety of personnel, facilities, equipment and procedures

satisfied current international regulations and goals	stationary tanks
scale and sludge removal	storage increase
scavenging	stress reduction
sea duty of cleaning crew eliminated	superport
sea-going tank ships	"Supership"
security simplified	supertanker
seepage sensing	supervision of entire process from single location
self-contained	surface tankers (rail, road)
separation of products	systematic operation
serial operations (now)	TCTFE
shirtsleeve environment	TLV
shoreside	tank bottoms
simulation	tank cooling side effect
single-point mooring	tank voiding, purging, inerting, ventilating and cleaning
slipping	temperature
socioeconomic factors	test criteria
software	threshold limit value
solvents	time sharing of facilities and personnel
speed of reaction	toxicity
spray systems maintained	tradeoff
standardized procedures	
standby safety facilitation	
static electricity	

training and upgrading personnel	Worldscale
trichlorotrifluoroethane	Yo-Yo
triple-point	zero discharge
tripping	
UEL	
ULCC	
Ucon	
ullage	
Ultral Large Crude Carrier	
Universe Class	
universal	
unlimited tank size	
upper explosive limit	
VLCC	
vapor pressure	
vapor recovery	
Very Large Crude Carrier	
viscosity	
visual feedback	
vulnerability	
waste management	
waterless solvents	
weathering decrease	
weight reduction	

## APPENDIX-B

Preliminary Operating Procedures for Reduction of Tanker  
Inerting and Cleaning Problems and for Pollution Abatement

The hypothetical procedures discussed herein are formulated to be closed-loop, continuous and safe. Beginning with Step-1, the proposed system monitors purity of the Freon, the cargo, and flow rates. The metering system is simple enough to be observed and operated effectively by current personnel without significantly new training. This system is based upon automated techniques using present day technology and off-the-shelf hardware. For the smaller operator or installation, manual operation is valid, safe, and reasonable. For larger facilities, automated techniques are likewise valid, safe, and reasonable while still using the same basic elements proposed for the smaller installation. This equipment and installation commonality allows for optimum logistics--spares deployment, minimum down-time, and minimum training for operators and maintenance personnel.

For the entire gamut of facility operations, no new or special tools or precautions are required. In fact, because of the improvement in safety and reduction of direct human contact with the cargo, the proposed system is judged to be more foolproof.

The fourth section of the five procedures discussed below suggests extension of the proposed system for fire-fighting--an added capability for merely the addition of manifolding and tankage with

compatible extinguishing material, also a Freon.

A. Cargo Removal with Simultaneous Tank Inerting

- 1) Tie-up ship at port-side cleaning facility.
- 2) Connect ground-potential static-electricity-defeating lines.
- 3) Hook-up input/output lines and vapor recovery units or bladder as determined from the notes below.
- 4) Run Built-In-Test (BIT) routine prior to the liquid Freon introduction to verify integrity of closed-loop system and pressurability.\*
- 5) Apply power to pumping system to empty tanks, as follows:
  - a) Pump vaporous Freon into shipboard cargo hold/tanks
  - b) Pump liquid cargo ashore, etc.

NOTE

Continue Step 5), filling the tank with Freon vapor until all of the cargo is unloaded such that the tank becomes inerted as the cargo is removed. At no point in this procedure has the cargo been exposed to oxygen from the ambient environment.

If cleaning is the next step, in preparation of a new higher-grade cargo, tank inspection, or maintenance procedures, go directly to Procedure B. If not, and ship is to dead head to next port of call, procedure may be terminated at this time. Bladders are to be used instead of vapor recovery units to prevent loss of the inerting material while providing the required amounts of tank breathing (expansion/contraction) due to the environment. Go to Procedure C.

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\*This may be accomplished by purely electrical means or by using a slug of vaporous Freon which is a fast, effective and less costly leak-test than application of the liquid Freon.

**B. Tank Cleaning\***

This procedure assumes completion of the inerting operation discussed above, if required. Also, this procedure assumes that as much cargo has been removed as is possible with the particular tank ship and support facility.

- 1) With vapor recovery units in place (as opposed to bladders where only inerting is required), switch from vaporous Freon injection to liquid Freon injection.
- 2) Pump Freon/cargo mixture from shipboard tanks to separation facility, as follows:
  - a) Maintain proper pressure equilization by Freon liquid input and by
  - b) Recovering escaping vapors through the vapor recovery units
  - c) Pass Freon/cargo mixture through scale/solid filtration, skimming or settling tank if sufficient Freon storage is held. Otherwise, go directly to Step-d).
  - d) Separate Freon/cargo mixture via distillation station, as follows:
    - (1) Vaporize and remove the Freon.
    - (2) Re-liquify the Freon for immediate re-use in the cleaning loop.

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\*This operation may also be applied to the safe cleaning of the various bilges, solid-waste-storage tanks, and other closed spaces aboard all commercial vessels (not just tankers). The stipulation of "commercial" vessels is made to classify vessels large enough to make application of this system economically feasible/valid.

- (3) Vaporize, remove, re-liquify and store cargo in temporary holding tanks or pump cargo directly into next (long term) storage medium.
  - (4) Collect and dispose of waste products.
  - e) Pump Freon into cargo hold/tanks as part of recycle.
  - f) Repeat cycle (a-e, incl.) continuously until in-line metering system indicates that the ship is empty (devoid of contamination within specified/acceptable limits).  
This step completes cargo transfer cycle to satisfy the waybill.
- 3) Run specified number\* of pure-Freon rinses through tanks to achieve proper level of purity (depending upon characteristics of past cargo, next anticipated cargo, their possible cross-product combined effects or the purity required for eventual human entry). This step satisfies the carrier.

#### NOTE

If next cargo is in this facility, it may be loaded using the same pumping station and lines without involving the Freon. Thus at this point the next cargo and its origin should be considered prior to the disconnection routine which follows. Further, ballasting must be considered in light of the next system.\*\*

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\*Beyond mere cargo removal, to a level of predetermined cargo-hold purity. This depends upon the next cargo and its peculiarities.

\*\*To totally eliminate contamination of tanks by sea-water it may be feasible to use the liquid Freon as the tanker's ballast between ports if the next port is equipped to cycle/purge and use the Freon in the tanks.

C. Total System Shut-Down (Next Cargo is not Available in this Port At this Time).

- 1) Close appropriate gate valves to prevent back flow.
- 2) Reverse the pumps to clear the system and drain the lines of Freon.\*
- 3) Add ballast as required.
- 4) Remove power from pumping system.
- 5) Disconnect input/output lines and bladders or vapor recovery units.
- 6) Disconnect ground-potential static-electricity-defeating lines.
- 7) Ship may untie and embark to next port of call.

D. Reload (Next Cargo is Located at this Port and is Ready for Loading).

- 1) Close appropriate gate valves to prevent back flow or contamination of next cargo.
- 2) Clear system to drain tanks and input/output lines prior to their disconnection or re-use (as in Step-2 of Procedure-C).
- 3) Close remaining valves etc., as required.
- 4) Block power to system to assure safety during line manipulations.
- 5) Disconnect, remove and store output lines that were attached to the ship for removal of its prior cargo unless able to use in 6), below.

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\*This draining operation siphons any residual material back behind valving such that there is no pollution/contamination of the port or loss of Freon.

- 6) Switch input lines and valving such that the next cargo will be loaded into the ship's tanks (not Freon). Use output lines too, if possible.
- 7) Fill tanks with new (next) cargo.
- 8) Commence with Step-1 of Procedure-C, above and complete all six steps prior to getting underway.

E. Port-Side Fire-Protection (An Added Capability for a Meager Additional Expense.)

This in-port fire-protection procedure uses the facilities required for the procedures of cargo-transfer through ship-cleaning (A through D, above) with the only additions including:

- 1) Additional set of valving to connect to standby Freon-extinguishment material.
- 2) Tankage for compatible extinguishment material (Freon-1301, Halon).

This procedure uses existing pumping techniques (used for cargo transfer and tank cleaning), as follows:

- 1) Close appropriate gate valves to prevent back flow or contamination of cargo, cleaning-Freon, or extinguishment-Freon.
- 2) Clear system to drain lines.
- 3) Switch input and output lines and valving such that the extinguishment-Freon will be pumped from its holding tankage, using both systems in parallel.
- 3a) While Step-3 is underway, attach appropriate nozzles to lines

if more direct control is needed. This step is to occur in parallel with Step-3.

- 4) Pump extinguishment material as required.
- 5) When emergency is relieved, re-establish a readiness posture in accordance with procedures A, B, and/or C.

F. Human Entry for Inspection or Modification

This procedure assumes completion of the cleaning operation discussed in Procedure B.

- 1) Complete Steps-1, 2, 4 and 5 of Procedure C.
- 2) Install Coppus-type blowers as per universal practice and ventilate tanks as required.
- 3) Certify gas-free situation.
- 4) Continue monitoring for Halides and explosive gases. Also continue monitoring available  $O_2$ .

## VITA

The author, Mr. Malcolm Mark Brauer, was born June 26, 1932 in New York to Mr. and Mrs. L. H. Brauer. His permanent mailing address is 3612 Southview Circle, Bryan, Texas 77801. He became interested in man-machine systems as a range instrumentation electronic technician with the USAF at AFMTC, Florida.

While a Senior Engineer with the Northrop Corporation for 10 years, the author received his Bachelor of Science degree in 1968 in Architecture at the University of Southern California, where he was a member of the honors program. He also accumulated 13 units towards the Masters degree in Aerospace Safety and Management at USC and was awarded the CMIP medal by Northrop.

He completed his Master of Science degree in Industrial Administration at the University of Dallas in 1972 while Division Human Factors Engineer with Texas Instruments. He took a non-funded scholastic leave of absence from TI to work on the subject system, after the V. A. Fogg disaster.

During his graduate work here at Texas A&M, Mr. Brauer was first a Research Assistant and then a Research Associate. He was given responsibility for the Human Factors Laboratory and the Human Factors Environmental Laboratory. He served as Graduate Student Council Representative for the School of Engineering and was selected for membership in Alpha Pi Mu and Tau Beta Pi, national honorary scholastic engineering fraternities.

This dissertation was typed by Mrs. Sally Brauer.